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Supplementary Material

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Appendix 1. PRISMA checklist

Section/topic	Item No	Checklist item	Reported on page No
Title			
Title	1	Identify the report as a systematic review, meta-analysis, or both	1
Abstract			
Structured summary	2	Provide a structured summary including, as applicable, background, objectives, data sources, study eligibility criteria, participants, interventions, study appraisal and synthesis methods, results, limitations, conclusions and implications of key findings, systematic review registration number	2
Introduction			
Rationale	3	Describe the rationale for the review in the context of what is already known	Introduction
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS)	Introduction
Methods			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (such as web address), and, if available, provide registration information including registration number	Methods
Eligibility criteria	6	Specify study characteristics (such as PICOS, length of follow-up) and report characteristics (such as years considered, language, publication status) used as criteria for eligibility, giving rationale	Methods
Information sources	7	Describe all information sources (such as databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched	Methods
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated	Appendix 4
Study selection	9	State the process for selecting studies (that is, screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis)	Methods
Data collection process	10	Describe method of data extraction from reports (such as piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators	Methods
Data items	11	List and define all variables for which data were sought (such as PICOS, funding sources) and any assumptions and simplifications made	Methods
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis	Methods
Summary measures	13	State the principal summary measures (such as risk ratio, difference in means).	Methods
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (such as I^2 statistic) for each meta-analysis	Methods
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (such as publication bias, selective reporting within studies)	Methods
Additional analyses	16	Describe methods of additional analyses (such as sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified	Methods
Results			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram	Results, Figure 1
Study characteristics	18	For each study, present characteristics for which data were extracted (such as study size, PICOS, follow-up period) and provide the citations	Results, Table 1, Appendices 6-7
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome-level assessment (see item 12).	Results, Appendices 7-8
Results of individual studies	20	For all outcomes considered (benefits or harms), present for each study (a) simple summary data for each intervention group and (b) effect estimates and confidence intervals, ideally with a forest plot	Results, Figures 2-4
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency	Results, Figures 2-4; Appendices 9-30
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see item 15)	Appendices 12, 14, 18, 21, 24, 27, 30
Additional analysis	23	Give results of additional analyses, if done (such as sensitivity or subgroup analyses, meta-regression) (see item 16)	Results, Figure 1, Appendices 12, 14, 18, 21, 24, 27, 30
Discussion			
Summary of evidence	24	Summarise the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (such as health care providers, users, and policy makers)	Discussion
Limitations	25	Discuss limitations at study and outcome level (such as risk of bias), and at review level (such as incomplete retrieval of identified research, reporting bias)	Discussion
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research	Discussion
Funding			
Funding	27	Describe sources of funding for the systematic review and other support (such as supply of data) and role of funders for the systematic review	Acknowledgements

Appendix 2. MOOSE checklist

Risk factors for dislocation after primary total hip replacement: meta-analysis of 125 studies involving approximately five million hip replacements

Criteria		Brief description of how the criteria were handled in the review
Reporting of background		
√	Problem definition	Factors influencing dislocation following primary total hip replacement (THR) are not well understood. We conducted a systematic review and meta-analysis to assess the associations of patient-, surgery-, implant-, and hospital-related factors with dislocation risk following primary THR
√	Hypothesis statement	Several patient-, surgery-, implant-, and hospital-related factors influence the risk of dislocation following primary THR
√	Description of study outcomes	Dislocation
√	Type of exposure	Patient-, surgery-, implant-, and hospital-related factors
√	Type of study designs used	Longitudinal studies (prospective or retrospective case control, prospective cohort, retrospective cohort, case-cohort, nested-case control, or clinical trials)
√	Study population	Patients followed for dislocation following primary THR
Reporting of search strategy should include		
√	Qualifications of searchers	
√	Search strategy, including time period included in the synthesis and keywords	Time period: from inception to March 8, 2019 The detailed search strategy can be found in Appendix 3
√	Databases and registries searched	MEDLINE, EMBASE, Web of Science, and Cochrane databases
√	Search software used, name and version, including special features	OvidSP was used to search EMBASE and MEDLINE EndNote used to manage references
√	Use of hand searching	We searched bibliographies of retrieved papers
√	List of citations located and those excluded, including justifications	Details of the literature search process are outlined in the flow chart. The citation list for excluded studies are available on request.
√	Method of addressing articles published in languages other than English	Not applicable
√	Method of handling abstracts and unpublished studies	Abstracts with no full text publications were not included.
√	Description of any contact with authors	We contacted authors of studies that did not provide adequate data in their studies
Reporting of methods should include		
√	Description of relevance or appropriateness of studies assembled for assessing the hypothesis to be tested	Detailed inclusion and exclusion criteria are described in the Methods section.
√	Rationale for the selection and coding of data	Data extracted from each of the studies were relevant to the population characteristics, study design, exposure, and outcome.
√	Assessment of confounding	We assessed confounding by ranking individual studies on the basis of different adjustment levels and performed sub-group analyses to evaluate differences in the overall estimates according to levels of adjustment.
√	Assessment of study quality, including blinding of quality assessors; stratification or regression on possible predictors of study results	Study quality was assessed based on the nine-star Newcastle–Ottawa Scale using pre-defined criteria namely: population representativeness, comparability (adjustment of confounders), ascertainment of outcome. Sensitivity analyses by several quality indicators such as study size, duration of follow-up, and adjustment factors. Cochrane risk of bias for clinical trials
√	Assessment of heterogeneity	Heterogeneity of the studies was quantified with I^2 statistic that provides the relative amount of variance of the summary effect due to the between-study heterogeneity and explored using meta-regression and stratified analyses
√	Description of statistical methods in sufficient detail to be replicated	Description of methods of meta-analyses, sensitivity analyses, meta-regression and assessment of publication bias are detailed in the methods. We performed random effects meta-analysis with Stata 15.
√	Provision of appropriate tables and graphics	Table 1; Figures 1-4; Appendices 9-30
Reporting of results should include		
√	Graph summarizing individual study estimates and overall estimate	Figures 1-4; Appendices 9-30
√	Table giving descriptive information for each study included	Appendix 7

√	Results of sensitivity testing	Sensitivity analysis was conducted to assess the influence of some large studies and low quality studies on the pooled estimate.
√	Indication of statistical uncertainty of findings	95% confidence intervals were presented with all summary estimates, I^2 values and results of sensitivity analyses
Reporting of discussion should include		
√	Quantitative assessment of bias	Sensitivity analyses indicate heterogeneity in strengths of the association due to most common biases in observational studies. The systematic review is limited in scope, as it involves published data. Individual participant data is needed. Limitations have been discussed.
√	Justification for exclusion	All studies were excluded based on the pre-defined inclusion criteria in methods section.
√	Assessment of quality of included studies	Brief discussion included in 'Methods' section
Reporting of conclusions should include		
√	Consideration of alternative explanations for observed results	Discussion
√	Generalization of the conclusions	Discussed in the context of the results.
√	Guidelines for future research	We recommend analyses of individual participant data
√	Disclosure of funding source	In "Acknowledgement" section

Appendix 3. Data sources and search strategy, eligibility criteria, and data extraction and quality assessment methods

Data sources and search strategy

We systematically conducted an electronic search of MEDLINE, Embase, Web of Science and The Cochrane library from inception of these databases to March 8, 2019. The search strategy was constructed by combining MeSH search terms and key words related to the population (e.g., “primary total hip replacement”), exposures (e.g., “age”, “sex”, “risk factor”), and outcome (e.g., “dislocation”, “instability”). The search was restricted to human studies with no limits on language. The full details of the MEDLINE search strategy are reported in appendix pp 7-8. All titles and abstracts of studies retrieved from the databases were screened by one reviewer (SKK) to assess their suitability for inclusion, after which full texts of potentially eligible papers were acquired. Full text evaluation was then conducted by two independent reviewers (SKK and MCB) based on the eligibility criteria. Disagreements regarding eligibility of articles were discussed and the opinion of a third reviewer (MRW) was sought when necessary to achieve consensus. The “cited by” function in Web of Science and the reference lists of relevant studies and review articles were assessed to identify any additional papers.

Eligibility criteria

Papers were eligible if they were longitudinal studies (prospective or retrospective cohorts, case-cohorts, nested-case controls, or clinical trials) that recruited patients who had undergone primary THR and reported on the associations of any patient-, surgery-, implant- or hospital-related factor (assessed at baseline or at time of surgery) with the risk of dislocation. Since more than 50% of dislocations occur in the first three months following THR^{1,2} and about a third manifest as late dislocations more than 5 years postoperatively,³ no restrictions were placed on the duration of follow-up. We excluded studies: (i) restricted to selected populations or patients with prevalent comorbidities (e.g. diabetes) and had no comparison or control groups; (ii) of revision THRs; (iii) that exclusively assessed risk factors for recurrent dislocation; (iv) that evaluated exposures (conditions) that developed post-surgery; (v) that involved only particular indications for THR such as hip fracture; and (vi) that included only hemiarthroplasty or hip resurfacing.

Data extraction and quality assessment

One reviewer (SKK) independently extracted qualitative and quantitative information into a standardised data collection spreadsheet. Data was extracted on study design, patient characteristics, type of exposures, and outcomes. A second reviewer (MCB) then independently checked the extracted data with that in the original papers. Any disagreements on extracted information between the two reviewers (SKK and MCB) were discussed and a third reviewer (MRW) was involved to achieve consensus. Authors were contacted to provide additional information if there was insufficient data (e.g. data for estimating a risk

ratio) reported. When the same study was described in multiple publications, the paper with the most comprehensive information was used. Methodological quality of each eligible study was assessed using the nine-star Newcastle-Ottawa Scale (NOS).⁴ NOS measures the quality of evidence from a score of zero to nine, based on three pre-defined domains including: (i) selection of participants; (ii) comparability; and (iii) ascertainment of outcomes of interest. The Cochrane Collaboration's risk of bias tool was used to assess the quality of randomised controlled trials (RCTs).⁵

References

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Appendix 4. Literature search strategy

Relevant studies, published from inception to March 8, 2019 (date last searched), were identified through electronic searches using MEDLINE, Embase, Web of Science, and Cochrane databases with no limits on language. Electronic searches were supplemented by scanning reference lists of articles identified for all relevant studies (including review articles), by hand searching of relevant journals and by correspondence with study investigators.

- 1 exp Arthroplasty, Replacement, Hip/ (24261)
- 2 primary.mp. (1433430)
- 3 exp Risk Factors/ (757067)
- 4 predictor.mp. (165039)
- 5 exp Risk Assessment/ (241419)
- 6 age.mp. (8254398)
- 7 exp Sex/ (7618)
- 8 gender.mp. (289037)
- 9 exp Body Mass Index/ (115624)
- 10 exp Body Weight/ (434494)
- 11 exp Obesity/ (194257)
- 12 exp Femur Head/ (9055)
- 13 femoral head.mp. (13361)
- 14 exp Femur/ (52415)
- 15 bearing.mp. (163097)
- 16 exp Bone Transplantation/ (30285)
- 17 bone-grafting.mp. (9443)
- 18 exp Osteotomy/ (33222)
- 19 cup inclination.mp. (280)
- 20 cup anteversion.mp. (187)
- 21 rim liner.mp. (13)
- 22 constrained liner.mp. (72)
- 23 exp Joint Instability/ (18869)
- 24 history of instability.mp. (53)
- 25 abductor.mp. (4811)
- 26 instability.mp. (113768)
- 27 exp Osteonecrosis/ (14700)
- 28 acetabul*.mp. (19874)
- 29 abduction.mp. (11448)
- 30 exp Smoking/ (139466)
- 31 exp Tobacco/ (29292)
- 32 alcohol.mp. (276997)
- 33 exp Socioeconomic Factors/ (422282)
- 34 socioeconomic.mp. (196851)
- 35 Diabetes Mellitus/ (111170)
- 36 diabetes.mp. (559194)
- 37 exp Hypertension/ (243676)
- 38 exp Heart Failure/ (111781)
- 39 exp Cardiovascular Diseases/ (2252580)
- 40 exp Coronary Artery Disease/ (56252)
- 41 exp Myocardial Infarction/ (167360)
- 42 exp Neoplasms/ (3140515)
- 43 malignancy.mp. (126587)

44 cancer.mp. (1525619)
 45 exp Comorbidity/ (98296)
 46 Charlson comorbidity index.mp. (4236)
 47 exp Arthritis, Rheumatoid/ (107717)
 48 exp Osteoarthritis/ (57822)
 49 exp Lupus Erythematosus, Systemic/ (56771)
 50 exp Respiratory Tract Diseases/ (1271873)
 51 exp Respiratory Tract Infections/ (341882)
 52 respiratory disease.mp. (15697)
 53 renal disease.mp. (54706)
 54 exp Kidney Failure, Chronic/ (89527)
 55 exp Kidney Diseases/ (486724)
 56 urinary disease.mp. (107)
 57 exp Urinary Tract Infections/ (44487)
 58 neurologic disease.mp. (3351)
 59 lumbar stenosis.mp. (708)
 60 exp Spinal Fusion/ (23190)
 61 exp Spinal Stenosis/ (5598)
 62 exp Discectomy/ (5017)
 63 discectomy.mp. (5671)
 64 exp Scoliosis/ (16867)
 65 exp Parkinson Disease/ (60940)
 66 exp Dementia/ (152129)
 67 exp Depression/ (106981)
 68 anterior approach.mp. (3581)
 69 posterior approach.mp. (4150)
 70 lateral approach.mp. (2388)
 71 anterolateral approach.mp. (599)
 72 posterolateral approach.mp. (640)
 73 exp Hip Dislocation/ (6014)
 74 dislocation.mp. (50116)
 75 instability.mp. (113768)
 76 exp Joint Instability/ (18869)
 77 luxation.mp. (4415)
 78 3 or 4 or 5 or 6 or 7 or 8 or 9 or 10 or 11 or 12 or 13 or 14 or 15 or 16 or 17 or 18 or 19 or 20 or 21 or 22 or 23 or 24 or 25 or 26 or 27 or 28 or 29
 or 30 or 31 or 32 or 33 or 34 or 35 or 36 or 37 or 38 or 39 or 40 or 41 or 42 or 43 or 44 or 45 or 46 or 47 or 48 or 49 or 50 or 51 or 52 or 53 or 54 or 55
 or 56 or 57 or 58 or 59 or 60 or 61 or 62 or 63 or 64 or 65 or 66 or 67 or 68 or 69 or 70 or 71 or 72 (13318407)
 79 73 or 74 or 75 or 76 or 77 (160210)
 80 1 and 2 and 78 and 79 (1058)
 81 limit 80 to humans (1050)

Each part was specifically translated for searching the other databases (EMBASE, Web of Science, and Cochrane databases)

Appendix 5. Statistical analyses

We pooled the incidence rate for dislocation (estimated from the number of dislocations within average follow-up period/total number of participants or procedures as reported) with 95% confidence intervals (CIs). Given that we employed binary data with low dislocation rates, the Freeman-Tukey variance stabilising double arcsine transformation was used.¹ Temporal trends in dislocation rates were evaluated using the median year of data collection/surgery reported by studies, as previously reported.² Relative risks (RRs) with 95% confidence intervals (CIs) were used as summary measures of associations between the different exposures and risk of dislocation. Fully-adjusted risk estimates were used for pooling when reported, otherwise crude RRs were calculated from the raw counts extracted from studies. For studies with zero events in one of the arms (exposure or control), the RR was calculated with the ‘opposite-arm’ continuity correction.³ Due to the variety of BMI cut-offs employed by the included studies, we used the following risk comparisons based on the data available: ≥ 25 vs. < 25 ; ≥ 30 vs. < 30 ; ≥ 35 vs. < 35 ; ≥ 50 vs. < 50 kg/m² and per unit increase in BMI, to ensure consistency in the pooling approach and enhance comparability and interpretation of findings as previously reported.^{4,5} Random-effects models were used to combine RRs to minimize the effect of heterogeneity.⁶ In the absence of substantial heterogeneity, fixed-effect models were employed. Heterogeneity was assessed using the Cochrane χ^2 statistic and the I^2 statistic.⁷ Several pre-defined study-level characteristics which may explain heterogeneity were explored using subgroup analyses and random effects meta-regression.⁸ Funnel plots and Egger’s regression symmetry tests were used to assess for publication bias or small study effects⁹ in pooled analysis involving 10 or more studies. The statistical analyses employed Stata MP 16 (Stata Corp, College Station, Texas, USA).

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Appendix 6. Reference list of 149 included articles

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Appendix 7. Characteristics of studies included in review

Author, year of publication	Year of study	Country	Mean/median age (years)	Study design	% Males	Mean/median follow-up duration (years)	No. of participants	No. of dislocations	Study quality
Salib, 2019	1988-2015	USA	71·0	Retrospective cohort	44·0	6·0	291	9	8
Angerame, 2018	2007-2014	USA	60·2	Retrospective cohort	40·5	0·8	6894	26	8
Giardina, 2018	2000-2016	Italy	61·9-67·5	Retrospective cohort	27·4	7·0	57 359	376	6
Ponzio, 2018	2010-2012	USA	64·7	Retrospective cohort	44·6	4·6	4538	66	8
Hwang, 2018	2013-2015	South Korea	72·0	Prospective cohort	30·5	1·8	167	4	8
Gausden, 2018	2012-2014	USA	64·5	Retrospective cohort	45·1	40 days	207 285	2842	6
Rondon, 2018	2000-2016	USA	69·3	Retrospective cohort	55·0	5·3	145	4	8
Li, 2018	2010-2012	China	42·8	Retrospective cohort	56·0	5·7	141	4	7
Malkani, 2018	1997-2014	USA	65-85+	Retrospective cohort	65-85+*	Up to 10·0	62 387	3042	7
Seagrave, 2017	2010-2015	Denmark	NR	Retrospective cohort	NR	1·9	1326	59	6
Cheng, 2017	2014-2015	Australia	61·0	RCT	45·0	12 weeks	73	2	NA
Rosenlund, 2017	2012-2014	Denmark	61·0	RCT	67·5	1·0	77	1	NA
Graves, 2017	1999-2014	Australia	NR	Retrospective cohort	NR	10·0	262 454	2023	7
Utsunomiya, 2017	1998-2010	Japan	57·8	Retrospective cohort	50·0	8·3	44	4	6
Shah, 2017	1999-2014	Australia	NR	Prospective cohort	NR	13·0	192 275	1219	7
Mjaaland, 2017	2008-2013	Norway	65·0	Prospective cohort	37·1	4·3	21 860	154	7
Abdel, 2017	2004-2006	USA	66·0	RCT	44·4	8·5	71	5	NA
Gofton, 2017	2005-2012	USA	62·2	Prospective cohort	45·0	5·7	809	9	8
Buckland, 2017	2005-2012	USA	<65-85+	Retrospective cohort	38·5	1·0	853 677	13 446	6
Houdek, 2017	1990-2013	USA	49·0	Prospective cohort	66·7	7·0	117	6	6
Faldini, 2017	2014-2017	Italy	64·5	Retrospective cohort	41·7	0·5	127	1	6
Zijlstra, 2017	2007-2015	Netherlands	60-74	Prospective cohort	NR	6·0	166 231	1095	6
Meneghini, 2017	2011-2014	USA	61·9	Retrospective cohort	46·5	5·0	342	40	8
Tarasevicius, 2017	2011-2014	Lithuania	67·4	Prospective cohort	36·7	2·5	2790	56	8
Prudhon, 2017	1994-2015	France	69·3	Retrospective cohort	37·6	13·5	1091	57	6
Perfetti, 2017	2005-2015	USA	64·5	Retrospective cohort	38·3	1·0	1868	32	7
Kurtz, 2017	2005-2014	USA	74·3	Retrospective cohort	38·0	9·0	315 784	4737	7
Charles, 2017***	2008-2013	USA	43·1	Case-control	35·9	4·2	78	2	6
Sadhu, 2017***	1997-2013	USA	59·5	Retrospective cohort	45·8	1·1	192	96	7
Werner, 2017	2005-2012	USA	<65-80+	Retrospective cohort	<65-80+	90 days	891 567	12 447	8
Cafri, 2017	2001-2013	USA	67·0	Retrospective cohort	43·0	1·0	28 772	236	8
Ancelin, 2016	1997-2007	France	47·8	Prospective cohort	47·8	11·4	282	9	7
Lee, 2016	2006-2013	Korea	49·0	Retrospective cohort	60·7	2·0	258	6	7

Author, year of publication	Year of study	Country	Mean/median age (years)	Study design	% Males	Mean/median follow-up duration (years)	No. of participants	No. of dislocations	Study quality
Sing, 2016	2005-2012	USA	<65-85+	Retrospective cohort	38·0	2·0	598 995	14 395	8
Blizzard, 2016	2005-2012	USA	<65-85+	Retrospective cohort	38·9	1·0	71 4654	20 551	7
Menendez, 2016	2002-2011	USA	65·9	Retrospective cohort	43·4	5 days	176 5115	2173	7
Malek, 2016	2010-2014	UK	70·5	Retrospective cohort	45·3	1·5	452	2	7
Tripuraneni, 2016	2012-2015	USA	60·2	Retrospective cohort	39·4	1·1	132	3	6
Wagner, 2016	1985-2012	USA	66·0	Prospective cohort	47·0	0·5	21 361	340	8
Hernigou, 2016	1990-2000	France	72·5	Case-control	39·1	14·0	430	36	6
Homma, 2016	2011-2015	Japan	74·8	Retrospective cohort	16·5	0·5	120	1	7
Oppler, 2016	2005-2014	USA	68·9	Retrospective cohort	48·6	1·5	148	37	8
Garcia-Rey, 2016	1992-2012	Spain	60·1	Retrospective cohort	55·6	2·22	1414	38	8
Surace, 2016	2005-2008	Italy	66·0	Retrospective cohort	45·8	3·5	387	6	5
Haughom, 2016	2002-2012	USA	63·1	Retrospective cohort	52·3	10·0	501	14	6
Fujishiro, 2016	2005-2010	Japan	62·5	Retrospective cohort	16·5	4·4	1555	50	7
Abdel, 2016	2003-2012	USA	63·0	Retrospective cohort	37·0	2·3	9784	206	6
Spaans, 2015	2010-2011	Netherlands	69·9	Retrospective cohort	15·1	1·0	465	8	7
Pitto, 2015	1999-2012	New Zealand	69·0	Prospective cohort	47·0	7·0	73 386	867	8
Epinette, 2015	2007-2011	France	68·2	Prospective cohort	39·0	4·1	273	7	8
Jamsen, 2015	1998-2009	Finland	NR	Prospective cohort	NR	4·2	1780	137	6
Tsukada, 2015	2006-2009	Japan	63·9	Retrospective cohort	13·9	7·5	316	7	6
Sheth, 2015	2001-2011	USA	66·0	Retrospective cohort	42·0	3·0	42 438	276	8
Maisongrosse, 2015	2004-2012	France	76·8	Retrospective cohort	29·2	4·9	502	2	7
Sanz-Reig, 2015	2005-2007	Spain	68·9	Retrospective cohort	40·7	6·8	454	22	7
Esposito, 2015	2007-2012	USA	66·0	Prospective cohort	42·3	0·5	7040	147	8
Delaunay, 2014	1988-2000	France	66·0	Retrospective cohort	56·4	9·8	193	11	7
Insull, 2014	1999-2012	New Zealand	NR	Prospective cohort	NR	NR	12 116	88	7
Kaneko, 2014	2008	Japan	65·2	Retrospective cohort	17·0	35·4 days	8321	117	7
Rathod, 2014***	2006-2011	USA	61·5	Retrospective cohort	44·0	1·9	675	3	7
Amlie, 2014	2008-2010	Norway	66·3	Retrospective cohort	34·4	2·4	1273	39	8
Caton, 2014	2000-2002	France	73·2	Retrospective cohort	42·5	10·0	320	27	7
Jamsen, 2014***	1998-2009	Finland	NR	Retrospective case control	NR	6·0	1188	NR	8
Rodriguez, 2014	2010	USA	59·5	Prospective cohort	45·0	1·0	120	1	7
Gerhardt, 2014	2008-2011	Netherlands	65·0	Retrospective cohort	45·8	1·0	190	8	6
Ravi, 2014c	2002-2009	Canada	68·0	Retrospective cohort	45·2	2·0	43 997	569	8
Jameson, 2014	NR	UK	69·1	Retrospective cohort	42·7	1·0	37 593	55	7
Jorgensen, 2014	2010-2011	Denmark	70·0	Retrospective cohort	45·9	90 days	2734	65	7
Bergh, 2014	1995-2011	Denmark, Finland,	68·9	Retrospective cohort	40·6	6·3	427 806	4222	8

Author, year of publication	Year of study	Country	Mean/median age (years)	Study design	% Males	Mean/median follow-up duration (years)	No. of participants	No. of dislocations	Study quality
		Norway, Sweden							
Ravi, 2014	2002-2009	Canada	68·0	Retrospective cohort	46·1	2·0	37 881	458	8
Prietzl, 2014	2002-2009	Germany	NR	Retrospective cohort	NR	2·8-6·1	1972	28	8
Nakashima, 2014	2006-2011	Japan	63·4	Retrospective cohort	16·8	2·5	634	11	8
Kostensalo, 2013	1996-2010	Finland	18-100	Prospective cohort	43·7	10·0	42 379	472	8
Stroh, 2013	2001-2010	USA	54·0	Retrospective cohort	46·6	5·0	807	10	6
Barrett, 2013	2010-2011	USA	62·3	RCT	55·2	1·0	87	1	NA
Leichtle, 2013***	1984-2005	Germany	NR	Retrospective case control	50·5	NR	111	56	6
Lachiewicz, 2013	2001-2006	USA	78·0	Prospective cohort	31·3	6·5	122	NR	6
Martin, 2013	2005-2010	USA	59·8	Retrospective cohort	40·0	0·5	88	4	7
Inacio, 2013	2001-2010	USA	65·7	Prospective cohort	42·5	3·0	35 140	307	8
Hailer, 2012	2005-2010	Sweden	<50->75*	Retrospective cohort	40·0	2·7	78 098	399	7
Lindgren, 2012	1992-2009	Sweden	70-73	Retrospective cohort	39·6	5·7	90 662	656	8
Howie, 2012	2001-2007	Australia	72·3	RCT	41·3	1·0	533	14	NA
Zhang, 2012***	1991-2006	China	62·2	Retrospective cohort	NR	12·8	307	12	6
Davis, 2011	1998-2005	UK	69·0	Prospective cohort	38·5	5·0	1617	42	8
Lazarinis, 2011	1992-2009	Sweden	NR	Retrospective cohort	49·0	10·0	4772	8	8
Molli, 2011	1996-2006	USA	61·6	Retrospective cohort	47·0	3·8	2368	5	6
Edmunds, 2011	1990-2008	UK	65·7-68·9	Retrospective cohort	35·0	1·0	3416	67	6
Clement, 2011	2006-2008	UK	68·1	Prospective cohort	NR	1·0	1359	29	8
Peter, 2011	1996-2008	Switzerland	70·6	Prospective cohort	44·4	1·0	2734	50	8
Bouchet, 2011	2003-2007	France	75·4	Retrospective cohort	45·5	4·3	213	5	6
Makela, 2011***	1998-2005	Finland	NR	Retrospective cohort	NR	NR	30 266	NR	7
Chee, 2010	1998-2003	UK	63·6	Prospective cohort	22·6	5·0	110	4	6
Dudda, 2010***	1978-2004	Switzerland	70·0	Case-control	34·0	31 days	826	175	7
Krenzel, 2010	1987-2008	USA	67·3	Retrospective cohort	43·9	6·6	3379	94	8
Amlie, 2010	2002-2009	Norway	68·5	Retrospective cohort	25·9	0·5-8	2572	53	8
Soohoo, 2010	1995-2005	USA	66·0	Retrospective cohort	57·0	90 days	138 399	1930	7
Bozic, 2010	2005-2007	USA	74·5	Retrospective cohort	NR	NR	57 047	NR	8
Tarasevicius, 2010	2003-2008	Lithuania	69·0	RCT	NR	1·0	276	10	NA
Kim, 2009	2000-2006	South Korea	57·0	Retrospective cohort	63·4	4·8	1648	60	6
Sexton, 2009	1999-2007	Australia	68·1	Prospective cohort	44·5	7·0	110 239	862	8
Hooper, 2009	1999-2006	New Zealand	<55->75*	Prospective cohort	NR	>90 days	42 665	514	5
Lubbeke, 2009	1998-2007	Switzerland	NR	Prospective cohort	NR	6 months	2601	46	7
Palan, 2009	1999-2002	UK	68·0	Prospective cohort	37·8	5·0	1089	24	6

Author, year of publication	Year of study	Country	Mean/median age (years)	Study design	% Males	Mean/median follow-up duration (years)	No. of participants	No. of dislocations	Study quality
Blom, 2008	1993-1996	UK	NR	Prospective cohort	NR	8 to 11	1567	53	6
Conroy, 2008***	1999-2004	Australia	NR	Prospective cohort	46·3	NR	65 992	531	8
Grant, 2008	NR	USA	56·6	Retrospective cohort	100·0	1·6	255	13	8
Andrew, 2008	1999-2002	UK	68·1	Prospective cohort	37·3	5·0	1421	24	6
Tsai, 2008	2000-2005	Taiwan	59·9	Retrospective cohort	44·6	3·5	204	9	7
Kim, 2008	1997-2005	Korea	47·6	Retrospective cohort	NR	1·0	450	20	6
Sadr, 2008	1997-2004	Sweden	30-80+	Retrospective cohort	NR	2·0	2106	53	8
Laffosse, 2007	NR	France	57·3	Prospective cohort	58·6	0·5	116	2	6
Arthursson, 2007	1987-2004	Norway	71-73	Prospective cohort	29·0	5·6-6·0	25 306	176	8
Peters, 2007	1995-2004	USA	60·0	Prospective cohort	44·0	4·3	296	4	6
Lubbeke, 2007	1996-2005	Switzerland	68·6	Prospective cohort	44·3	5·0	2495	53	8
Karrholm 2006	1992-2004	Sweden	NR	Retrospective cohort	NR	2·0	142 000	644	8
Tarasevicius, 2006	NR	Lithuania	70·0	RCT	63·6	1·0	33	1	NA
Ibrahim, 2005	2000-2002	UK	68·1	Retrospective cohort	33·9	1·0	343	3	5
Namba, 2005	2001-2002	USA	65·4	Retrospective cohort	42·4	1·0	1071	8	6
Berry, 2005	1969-1999	USA	64·0	Prospective cohort	48·8	9·5-10·5	21 047	868	8
Sierra, 2005	1992-2002	USA	83·0	Retrospective cohort	42·0	2·2	150	8	8
Zwartele, 2004	1996-1999	Netherlands	66·9	Prospective cohort	14·0	2·0	410	17	8
Lawton, 2004	1990-1994	USA	NR	Retrospective cohort	NR	NR	250	14	7
Suh, 2004	1993-1998	South Korea	53·4	Retrospective cohort	66·3	1·0	346	17	8
Bystrom, 2003	1987-2000	Norway	72·0	Prospective cohort	29·0	5·3	42 987	311	8
Weeden, 2003	1994-2000	USA	62·3	Retrospective cohort	41·0	4·4	945	8	6
van Stralen, 2003	1995-1998	Netherlands	69·5	Retrospective cohort	26·0	2·5	884	12	6
Mahomed, 2003	1995-1996	USA	≥65*	Retrospective cohort	NR	90 days	61 568	1909	8
von Knoch, 2002	1969-1995	USA	66·0	Retrospective cohort	48·5	11·3	19 680	513	7
Jolles, 2002***	1991-1998	Switzerland	69·0	Retrospective cohort	42·9	NR	42	21	7
Downing, 2001	1995-1997	UK	66·0	Retrospective cohort	45·0	1·0	100	4	6
White, 2001	NR	USA	NR	Case-control	NR	0·5	1515	55	5
Katz, 2001	1995-1996	USA	74·3	Retrospective cohort	36·0	90 days	58 521	1834	7
Goldstein, 2001	1993-1999	USA	NR	Retrospective cohort	NR	1·0	1000	17	6
Chiu, 2000	1994-1997	Taiwan	52·4	RCT	61·7	3·2	180	2	NA
Li, 1999	1989-1992	USA	66·0	Retrospective cohort	50·0	7·0	812	24	6
Woolson, 1999	1985-1995	USA	64·0	Retrospective cohort	50·2	3 months	315	14	7
Mallory, 1999	1992-1996	USA	63·0	Retrospective cohort	46·0	3·0	1518	12	6
Kelley, 1998	1995-1996			RCT	26·7	1·0	31	5	NA
Kelley, 1998	1984-1994	USA	63·0	Retrospective cohort	32·1	5·4	308	5	7

Author, year of publication	Year of study	Country	Mean/median age (years)	Study design	% Males	Mean/median follow-up duration (years)	No. of participants	No. of dislocations	Study quality
Pellicci, 1998** (***)	1991-1996	USA	NR	Retrospective cohort	NR	NR	284 (790)	11 (16)	6
Paterno, 1997	1983-1994	USA	58·8-61·2	Retrospective cohort	32·0	5 to 6	391	17	8
Cobb, 1996	1985-1991	USA	NR	Retrospective cohort	NR	2·0	4117	75	6
Hedlundh, 1996***	1979-1991	Sweden	69·3	Retrospective cohort	44·1	NR	4230	129	8
Lehman, 1994	1983-1990	USA	48-52	Retrospective cohort	69·8	2·0	202	6	6
Carlson, 1987	1982-1983	USA	65·2	Retrospective cohort	87·8	16-17 days	74	5	5
Vicar, 1984	1976-1980	USA	64·8	Retrospective cohort	38·4	3·2	269	9	6
Roberts, 1984	1975-1979	USA	60·0	Retrospective cohort	50·0	10 weeks	175	5	6
Robinson, 1980	1972-1978	USA	61·5	Retrospective cohort	41·4	1·6	316	12	7
Weaver, 1975	1969-1973	USA	NR	Retrospective cohort		2·2-3·5	60	4	5

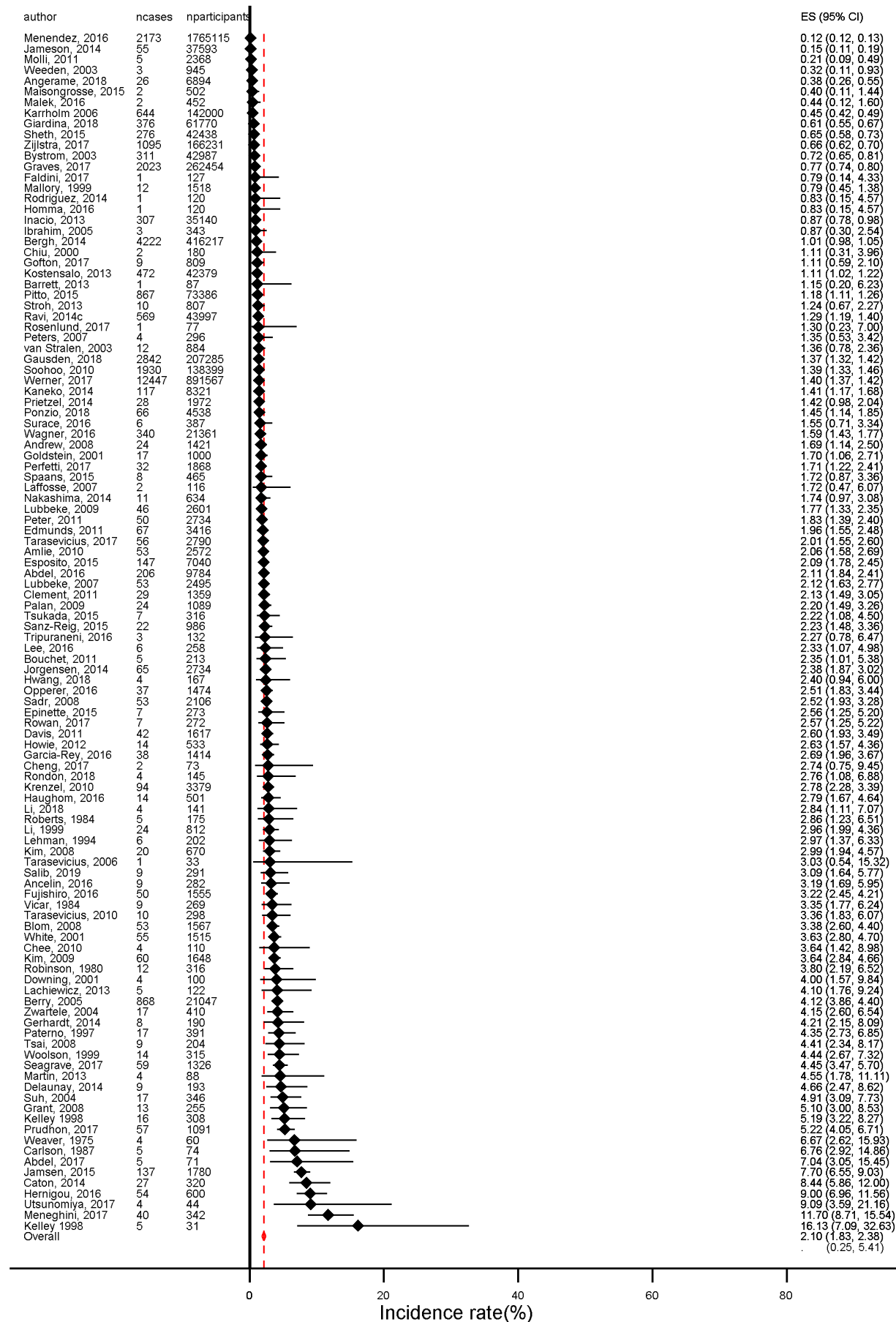
*, age range of participants; **, based on two studies; ***, the following studies were not included in incidence rates calculation because the sample was very selected, there was no data on follow-up duration or there was no data on number of dislocation events; NA, not applicable; NR, not reported; RCT, randomised controlled trial

Appendix 8. Cochrane risk of bias assessment for randomised controlled trials

	<i>Random sequence generation</i>	<i>Allocation concealment</i>	<i>Blinding of participants & personnel</i>	<i>Blinding of outcome assessments</i>	<i>Incomplete outcome data</i>	<i>Selective reporting</i>	<i>Other bias</i>
Kelly, 1998	?	?	-	-	+	+	-
Chiu, 2000	?	?	-	-	+	+	-
Tarasevicius, 2006	?	?	-	-	-	+	-
Tarasevicius, 2010	?	?	-	-	+	+	-
Howie, 2012	+	+	-	-	+	+	?
Barrett, 2013	+	?	-	-	+	+	?
Abdel, 2017	+	+	?	-	+	+	?
Cheng, 2017	+	+	+	+	+	+	?
Rosenlund, 2017	+	+	+	?	+	+	+

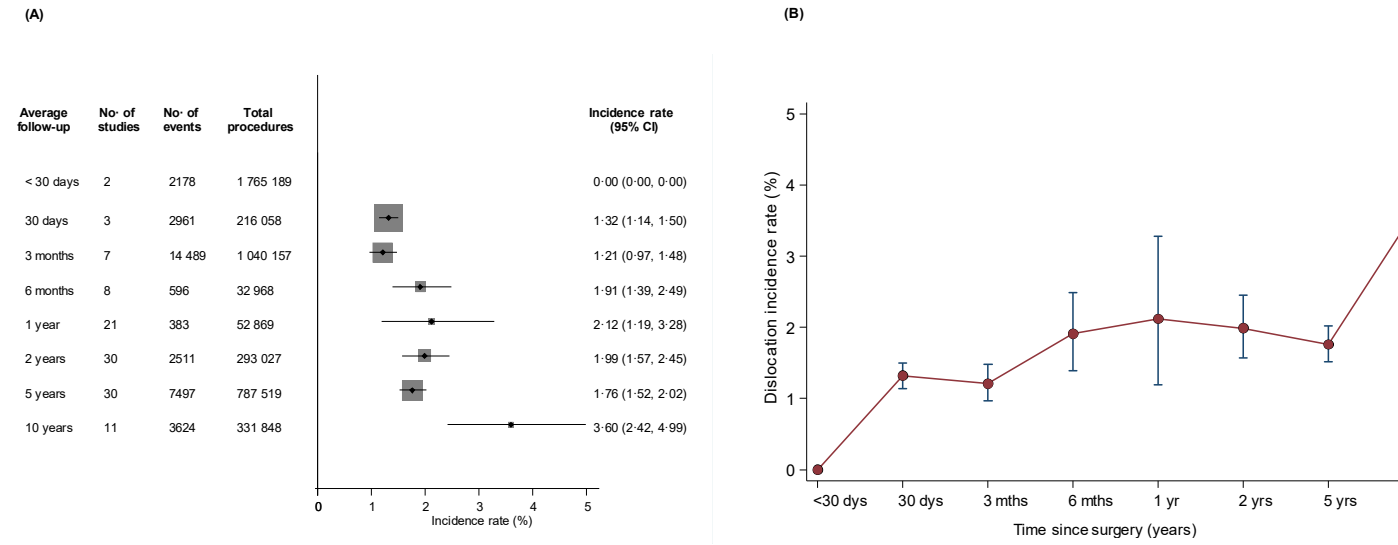
+	Low risk of bias
?	Unclear risk of bias
-	High risk of bias

Appendix 9. Incidence rate of dislocation across 112 relevant studies



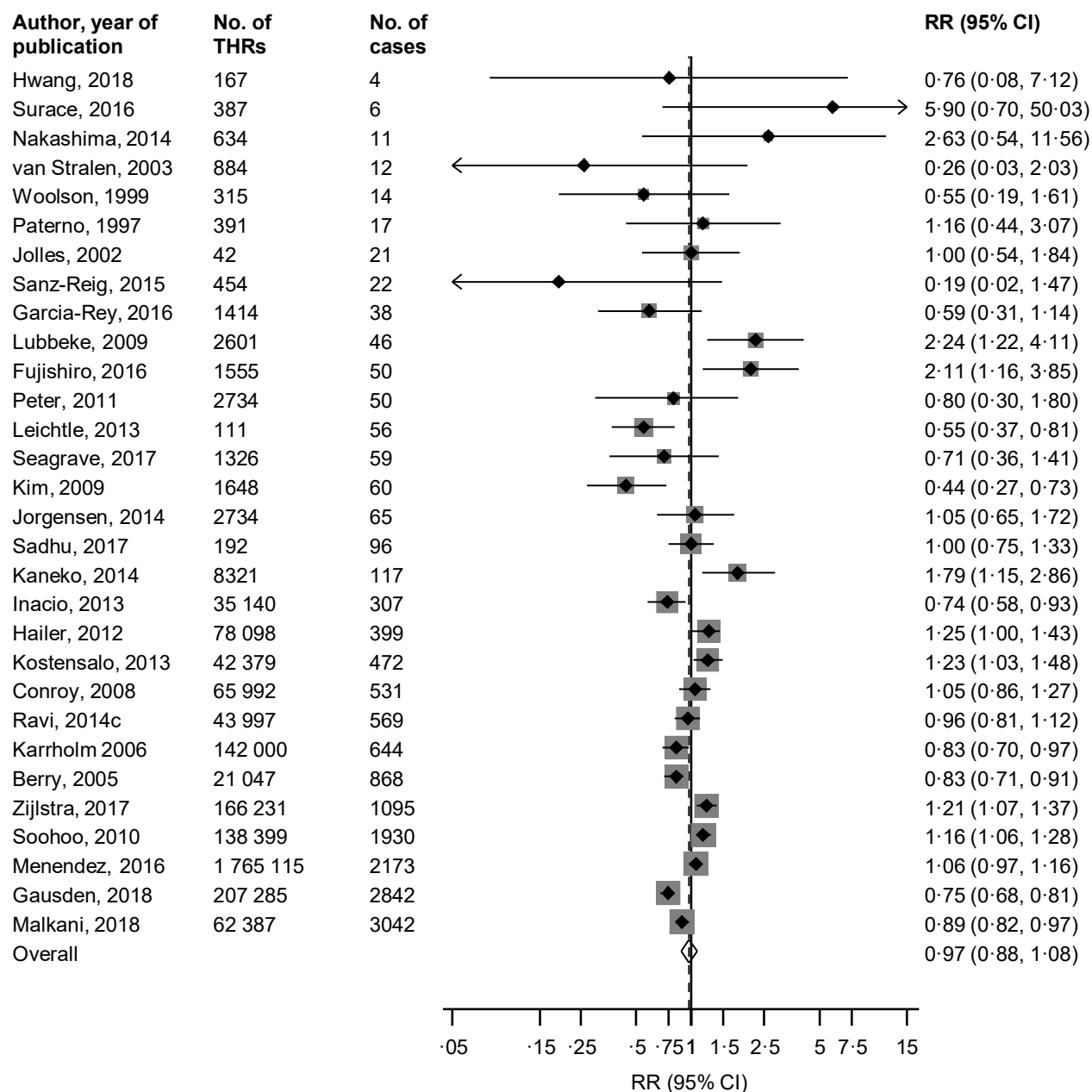
Only unique studies were included in pooled analysis to avoid the potential of double counting

Appendix 10. Incidence of dislocation following primary total hip replacement at specific average follow-up periods



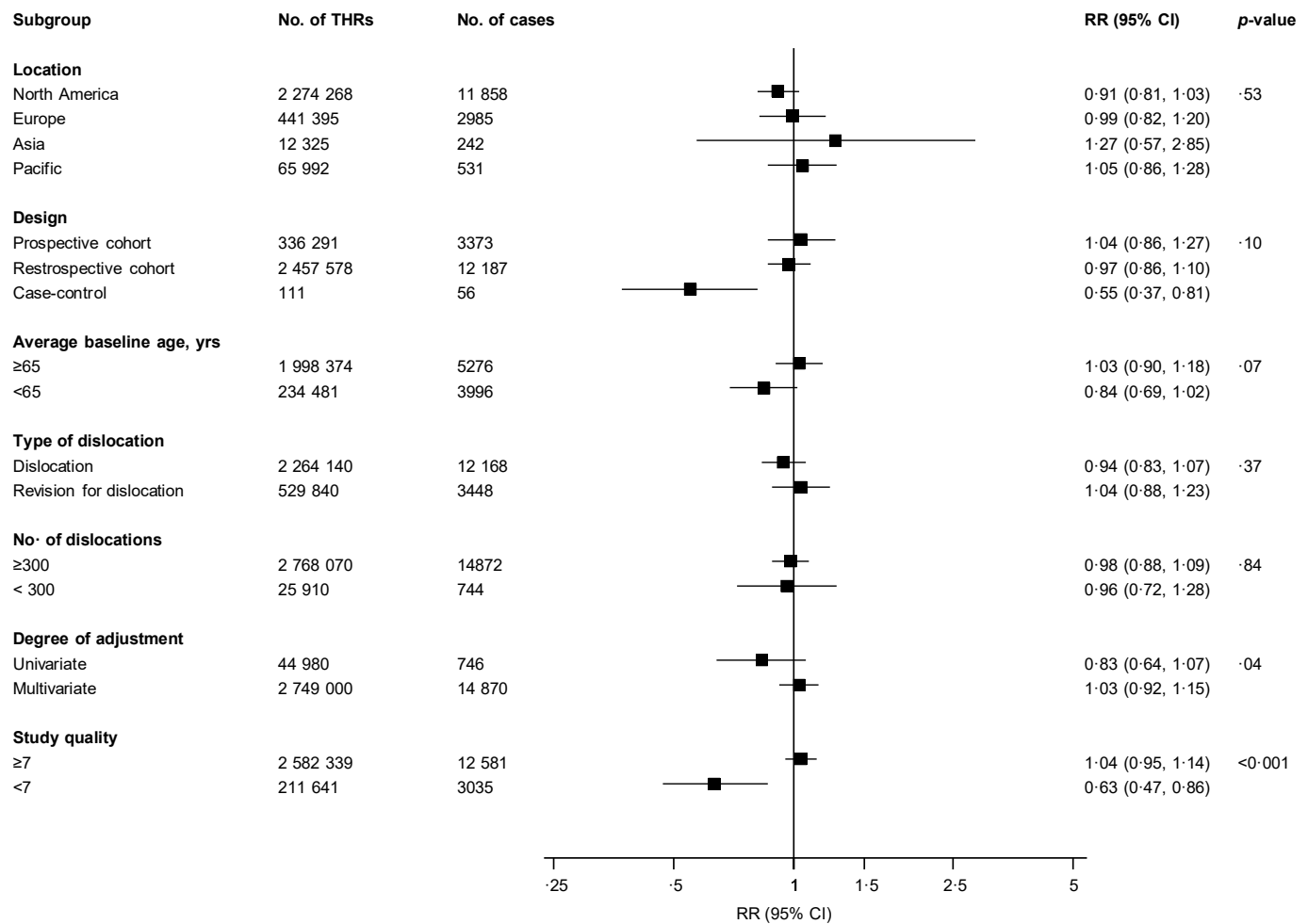
Capped vertical bars represent 95% confidence intervals

Appendix 11. Risk of dislocation comparing males to females



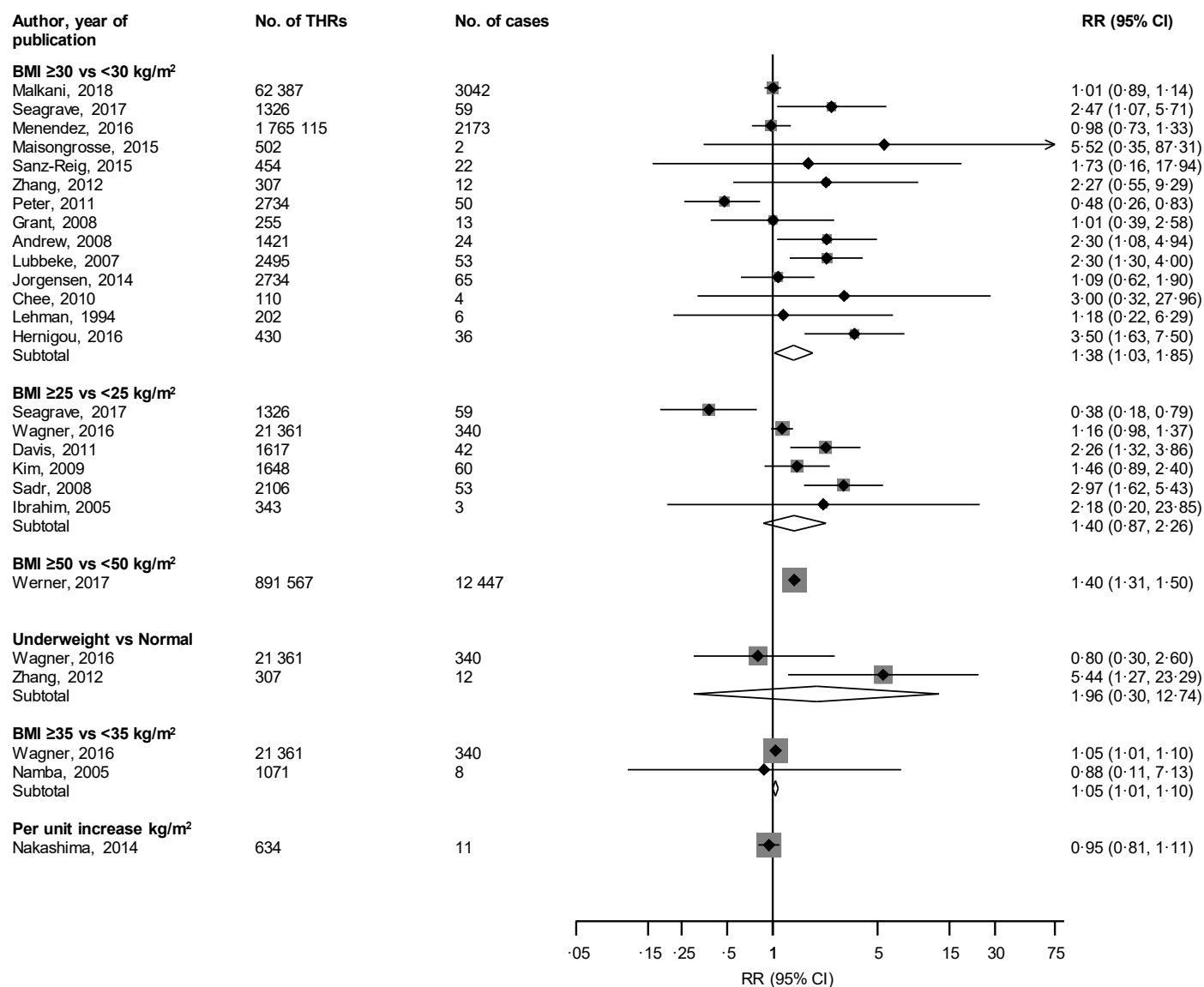
CI, confidence interval (bars); RR, relative risk; THR, total hip replacement

Appendix 12. Risk of dislocation comparing males to females, grouped according to study level characteristics



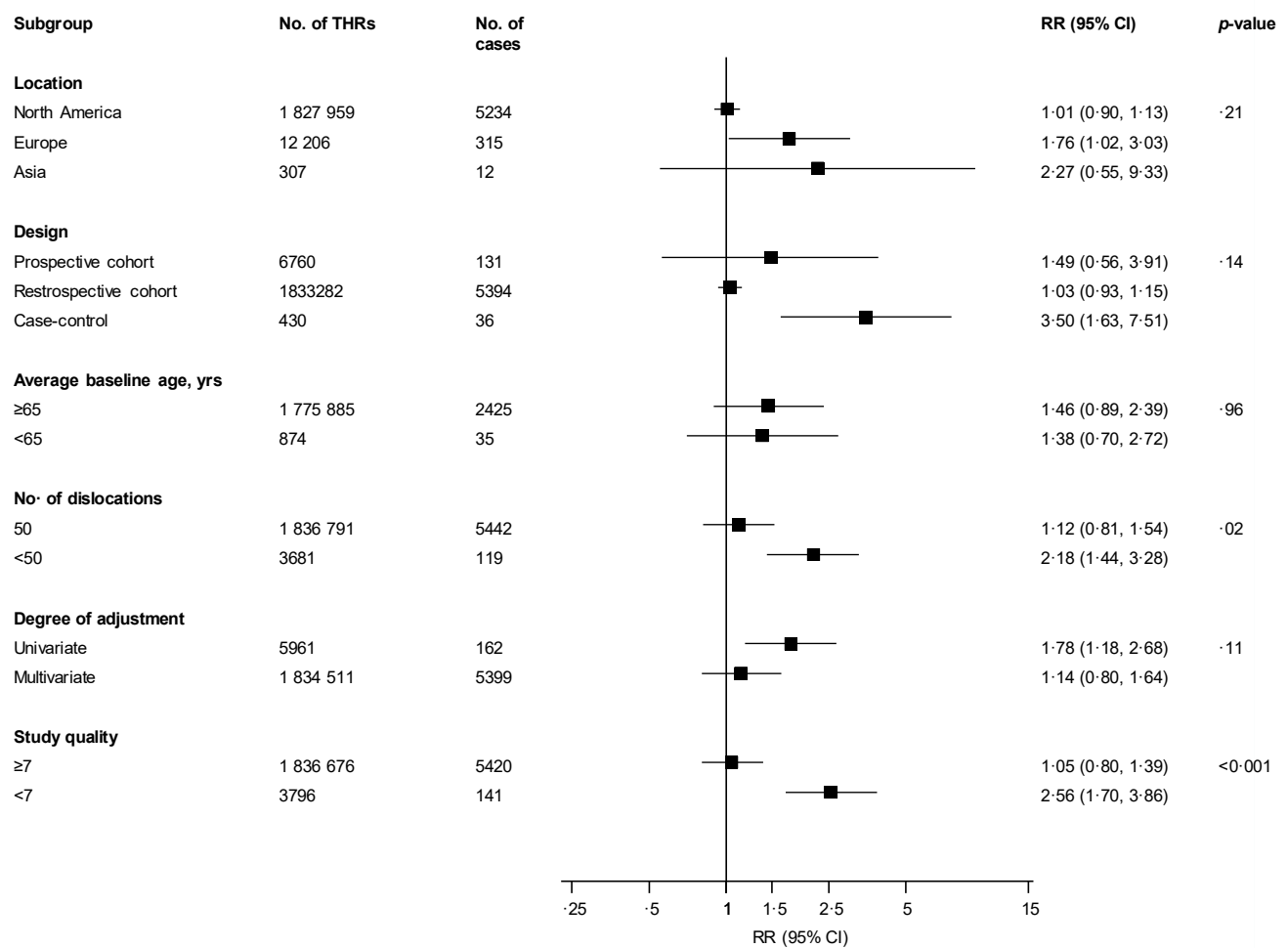
CI, confidence interval (bars); RR, relative risk; *p*-values are for meta-regression

Appendix 13. Risk of dislocation for BMI comparisons



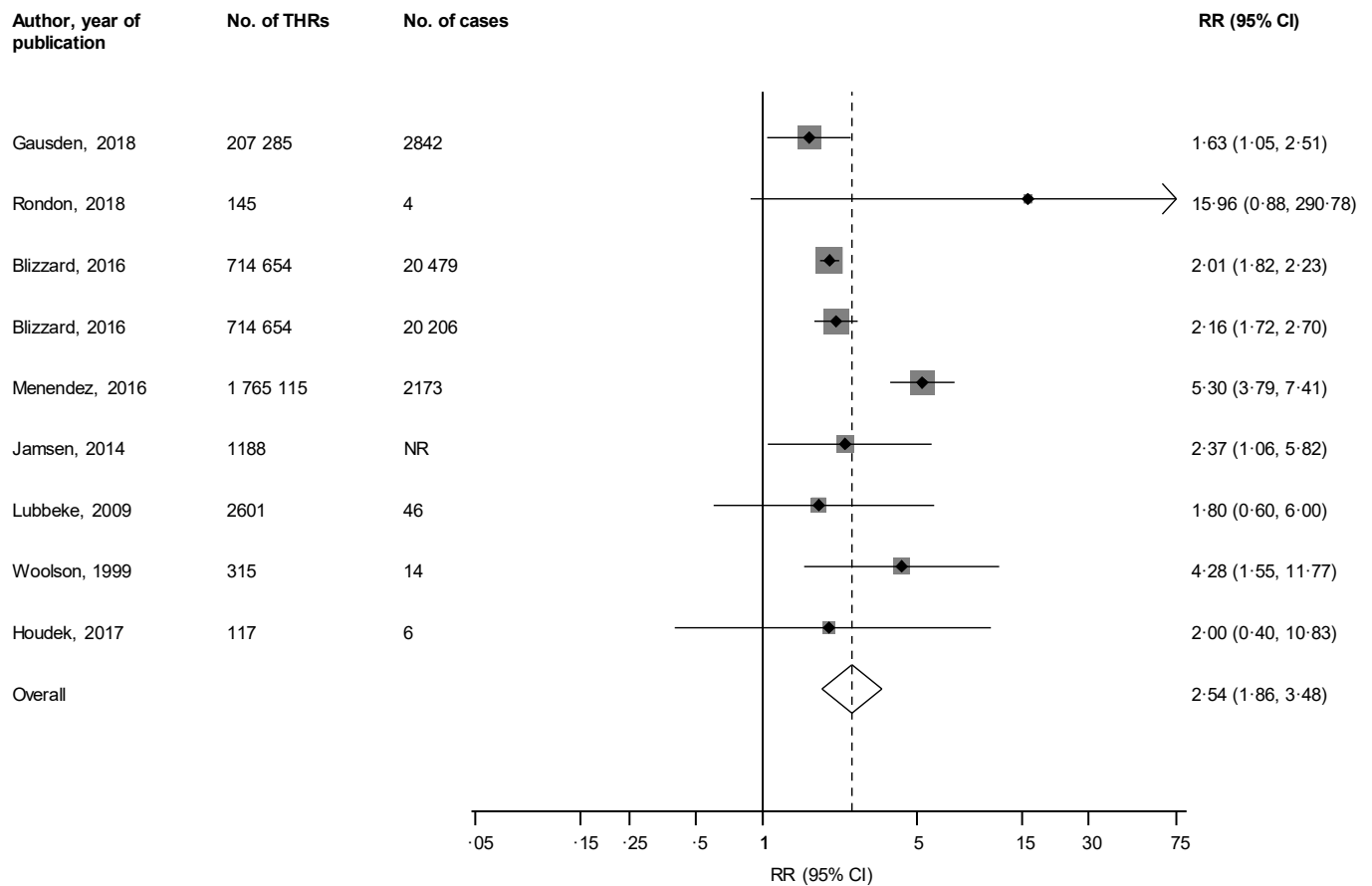
BMI, body mass index; CI, confidence interval (bars); RR, relative risk; THR, total hip replacement

Appendix 14. Risk of dislocation comparing individuals with a BMI ≥ 30 versus <30 kg/m², grouped according to study level characteristics



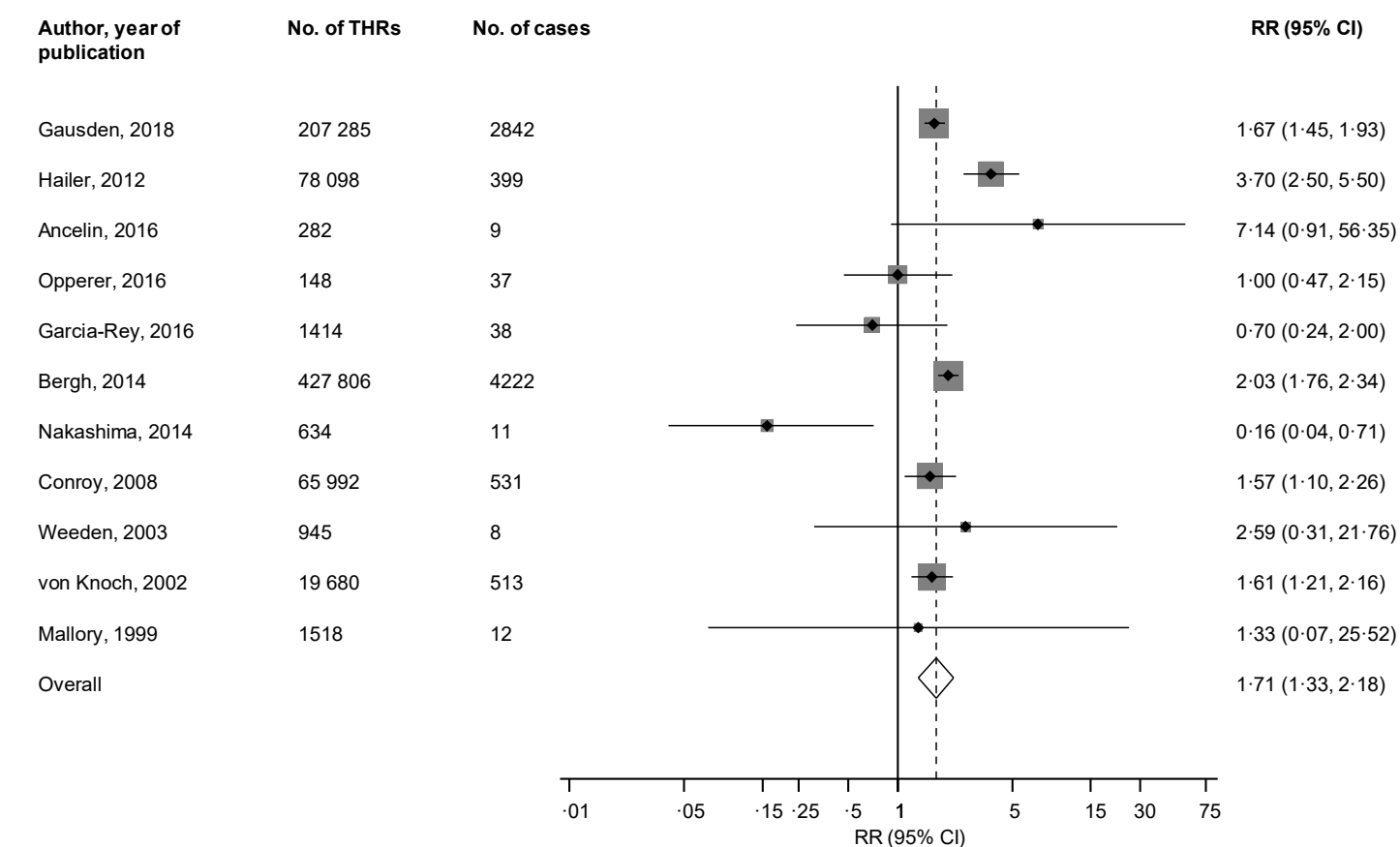
BMI, body mass index; CI, confidence interval (bars); RR, relative risk; THR, total hip replacement; *p*-values are for meta-regression

Appendix 15. Risk of dislocation comparing patients with neurological disorder versus no neurological disorder



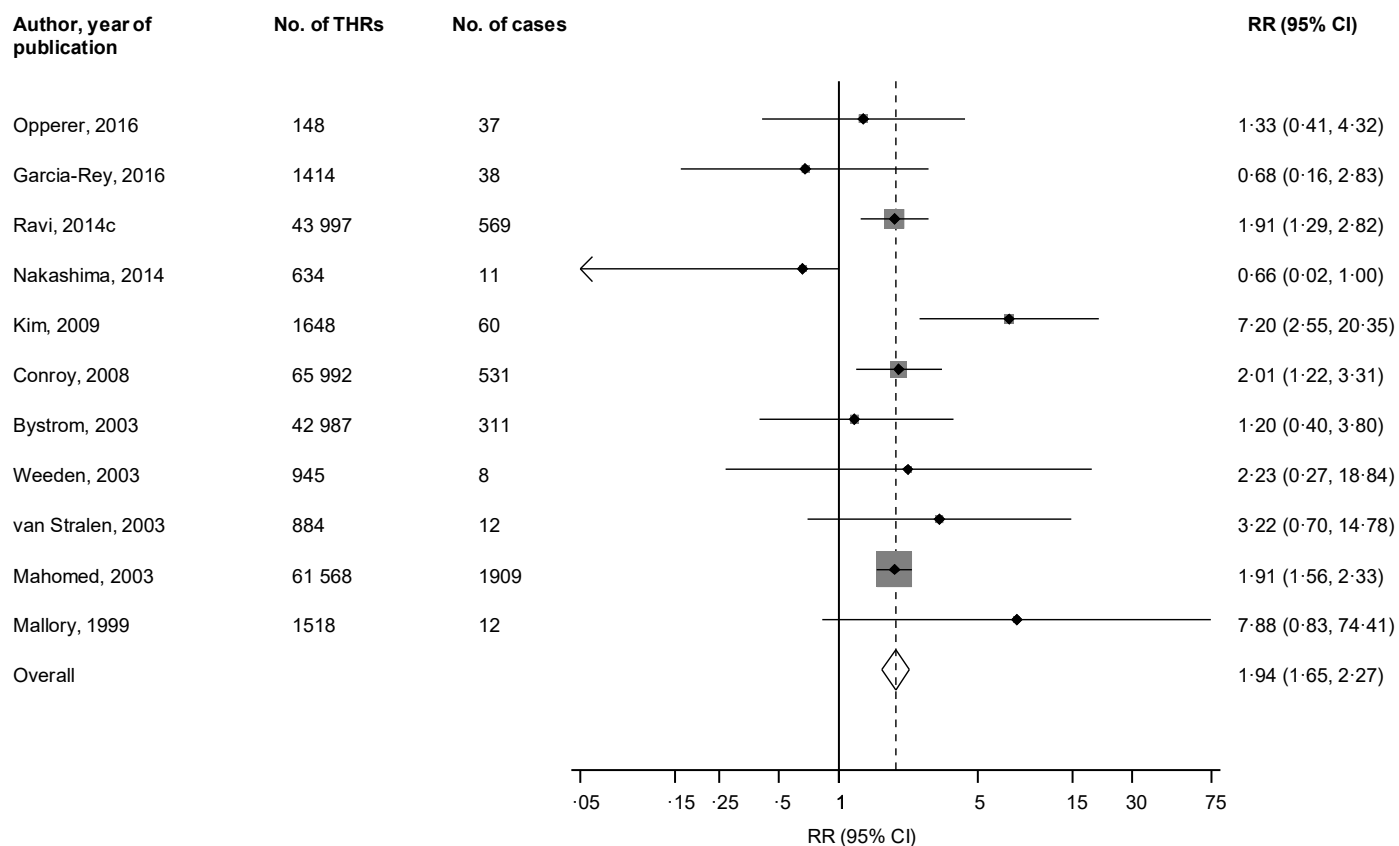
CI, confidence interval (bars); NR, not reported; RR, relative risk; THR, total hip replacement

Appendix 16. Risk of dislocation comparing a surgical indication of avascular necrosis versus osteoarthritis



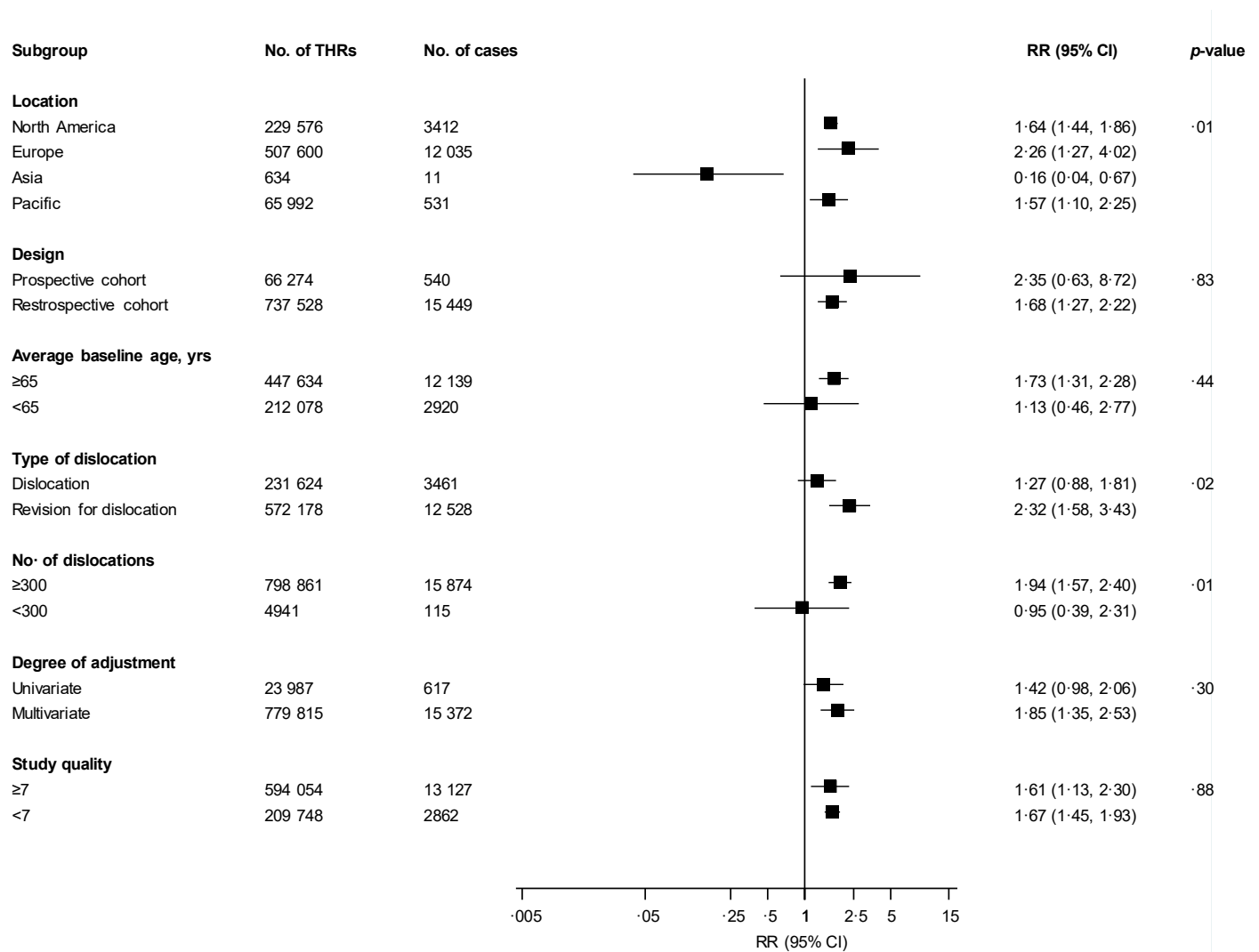
CI, confidence interval (bars); RR, relative risk; THR, total hip replacement

Appendix 17. Risk of dislocation comparing a surgical indication of rheumatoid arthritis versus osteoarthritis



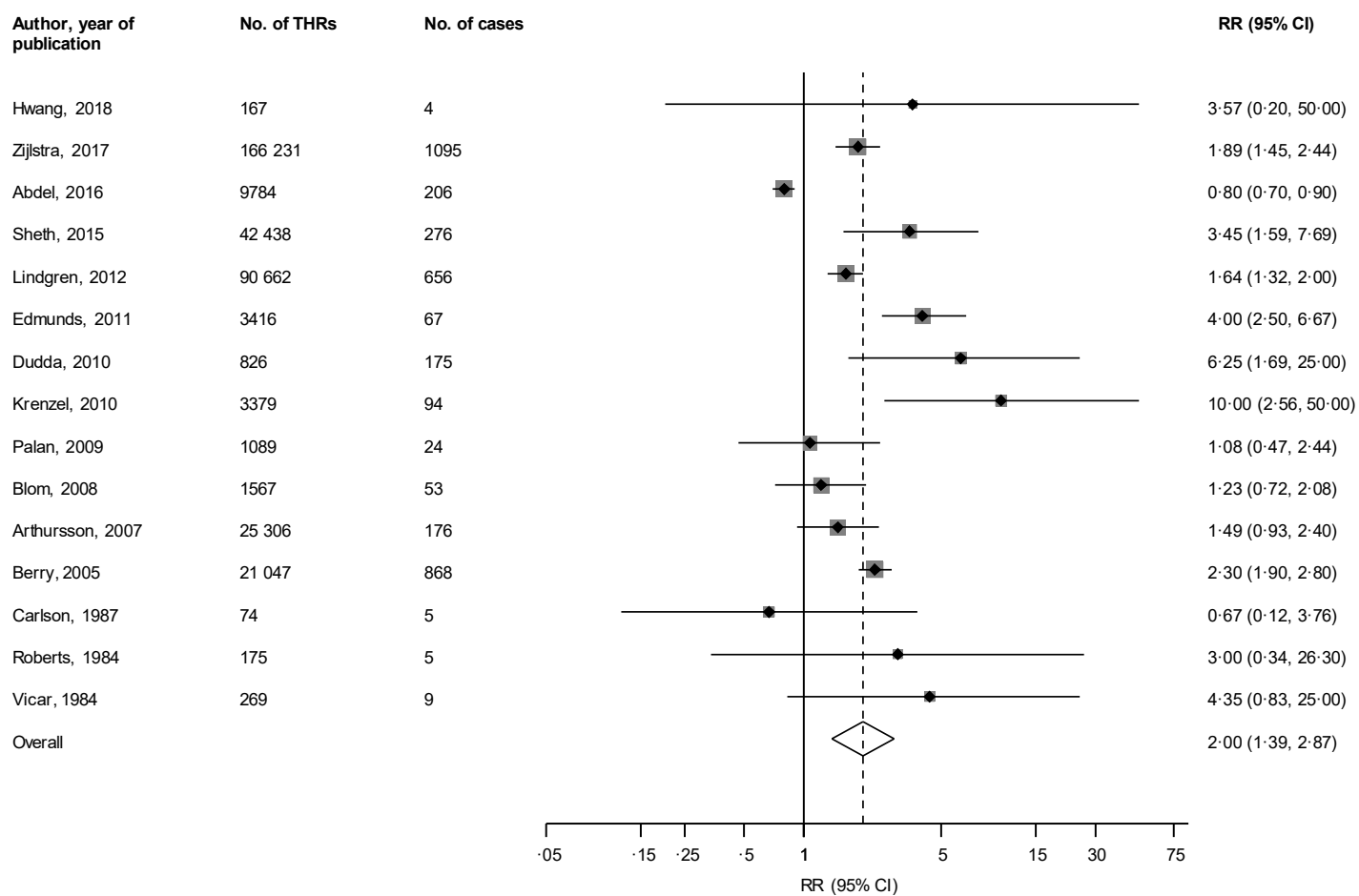
CI, confidence interval (bars); RR, relative risk; THR, total hip replacement

Appendix 18. Risk of dislocation comparing a surgical indication of avascular necrosis versus osteoarthritis, grouped according to study level characteristics



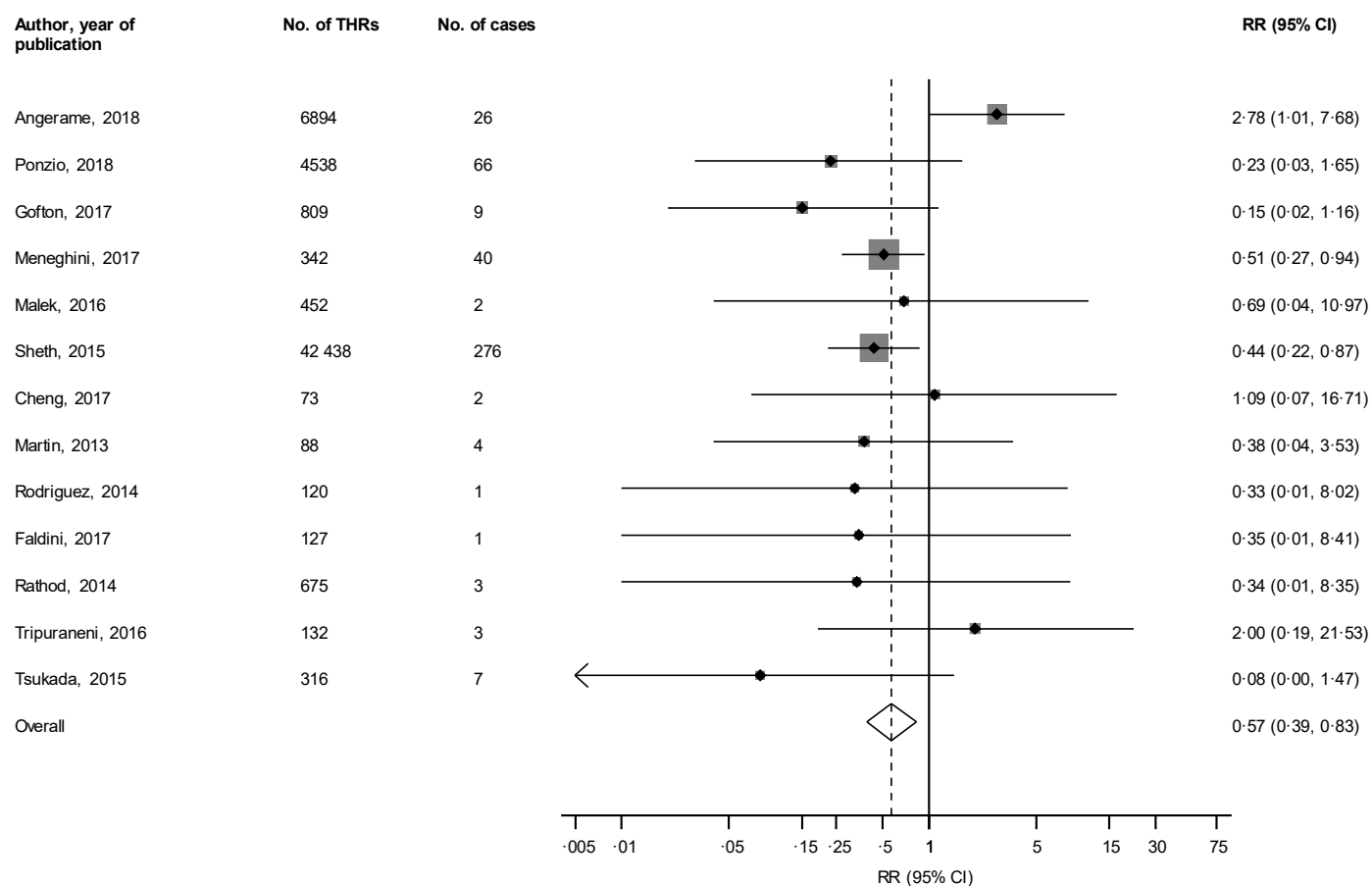
CI, confidence interval (bars); RR, relative risk; THR, total hip replacement; *p*-values are for meta-regression

Appendix 19. Risk of dislocation comparing a posterior with an anterolateral approach



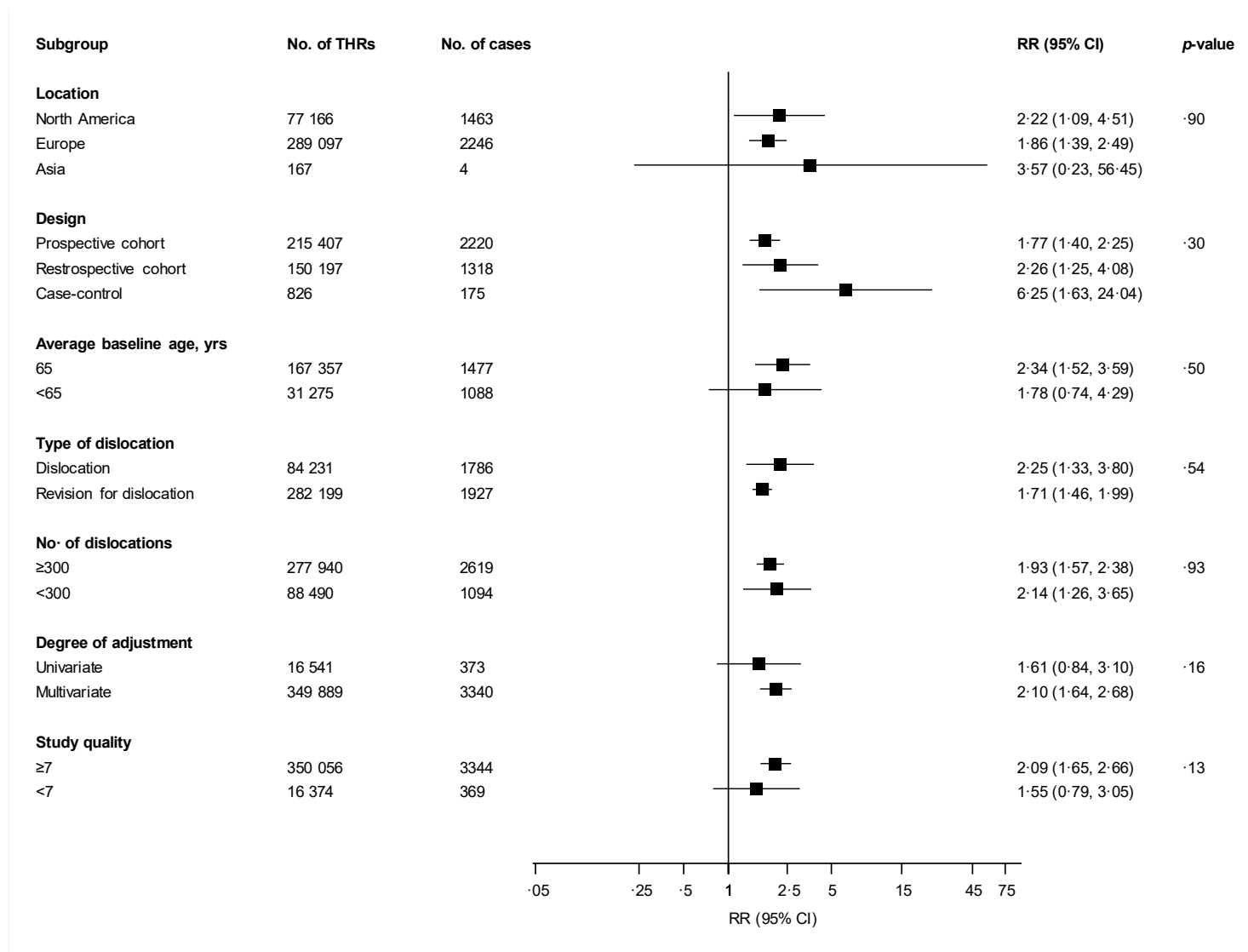
CI, confidence interval (bars); RR, relative risk; THR, total hip replacement

Appendix 20. Risk of dislocation comparing a direct anterior with a posterior approach



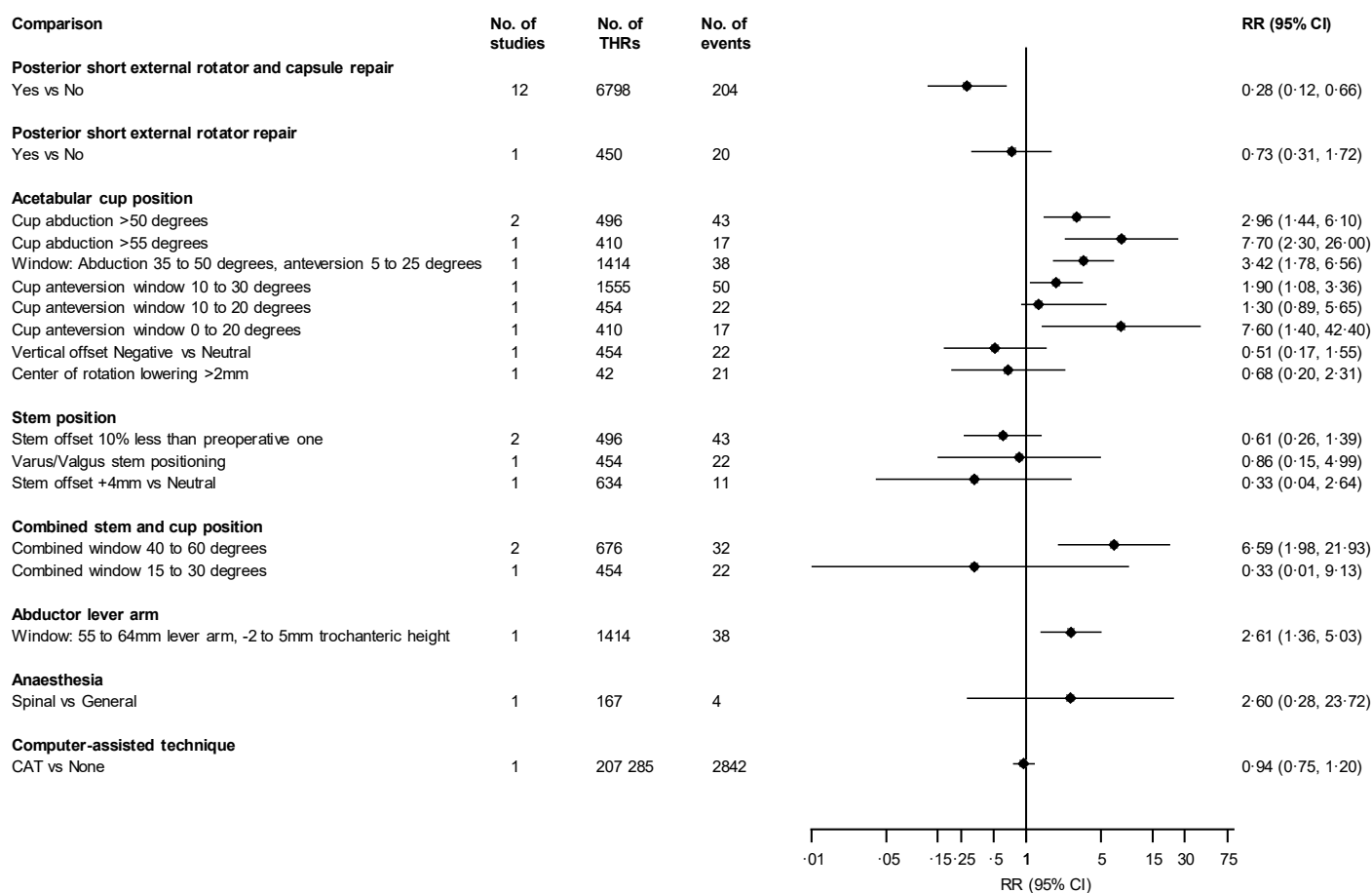
CI, confidence interval (bars); RR, relative risk; THR, total hip replacement

Appendix 21. Risk of dislocation comparing a posterior with an anterolateral approach, grouped according to study level characteristics



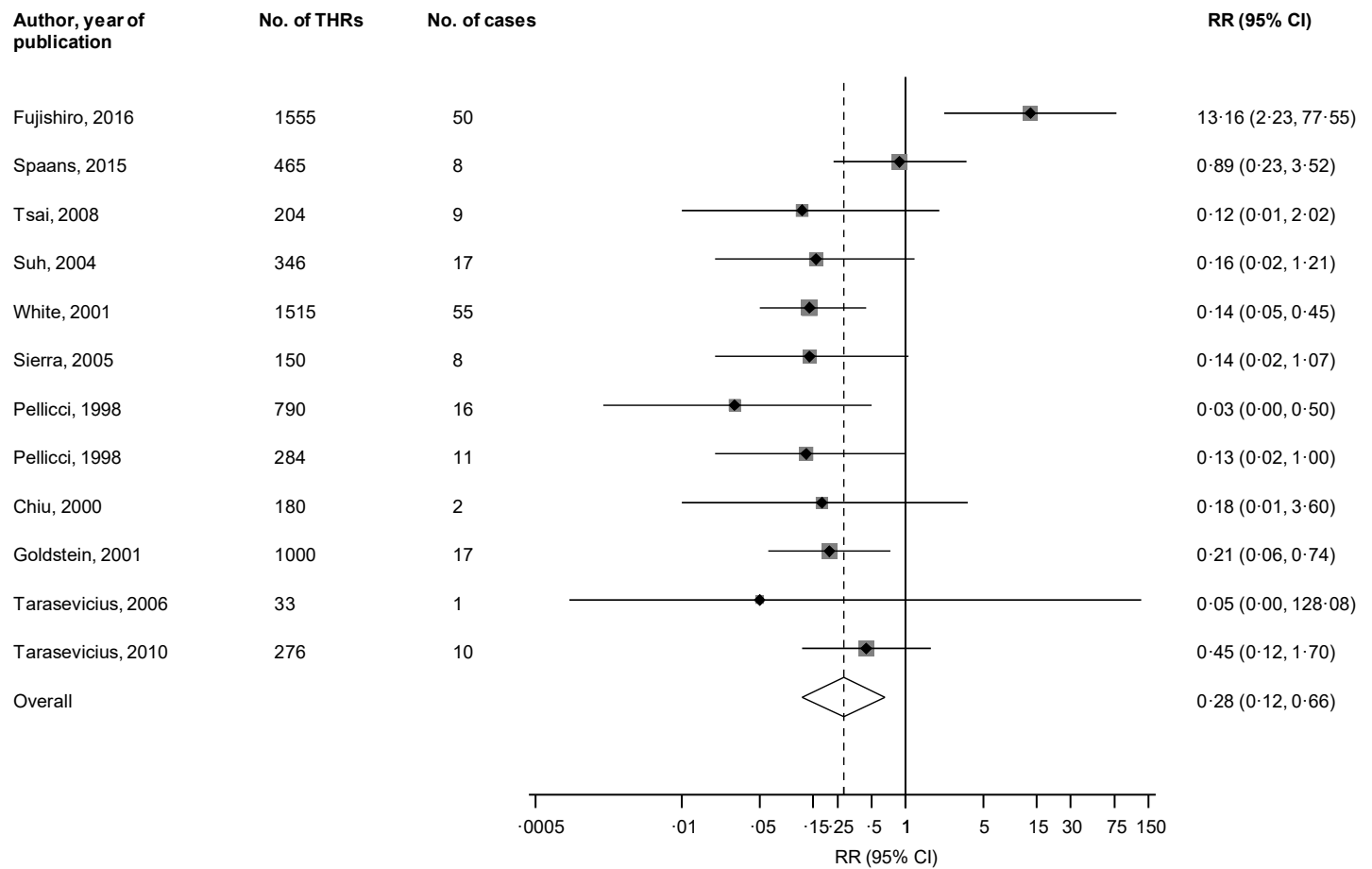
CI, confidence interval (bars); RR, relative risk; THR, total hip replacement; *p*-values are for meta-regression

Appendix 22. Summary associations of surgery-related factors and risk of dislocation



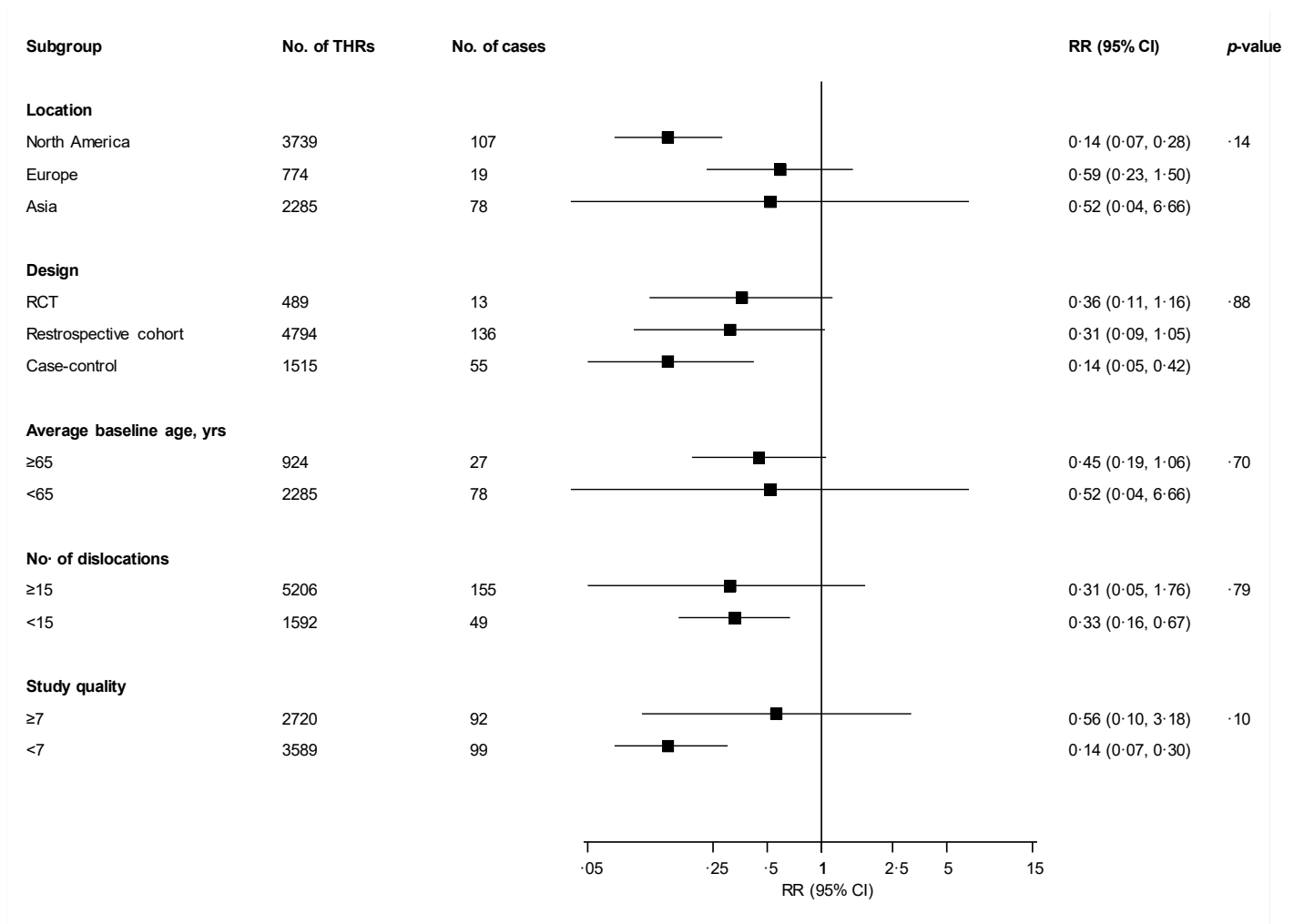
CAT, computer-assisted technique; CI, confidence interval (bars); RR, relative risk; THR, total hip replacement

Appendix 23. Risk of dislocation comparing a posterior short external rotator and capsule repair versus none



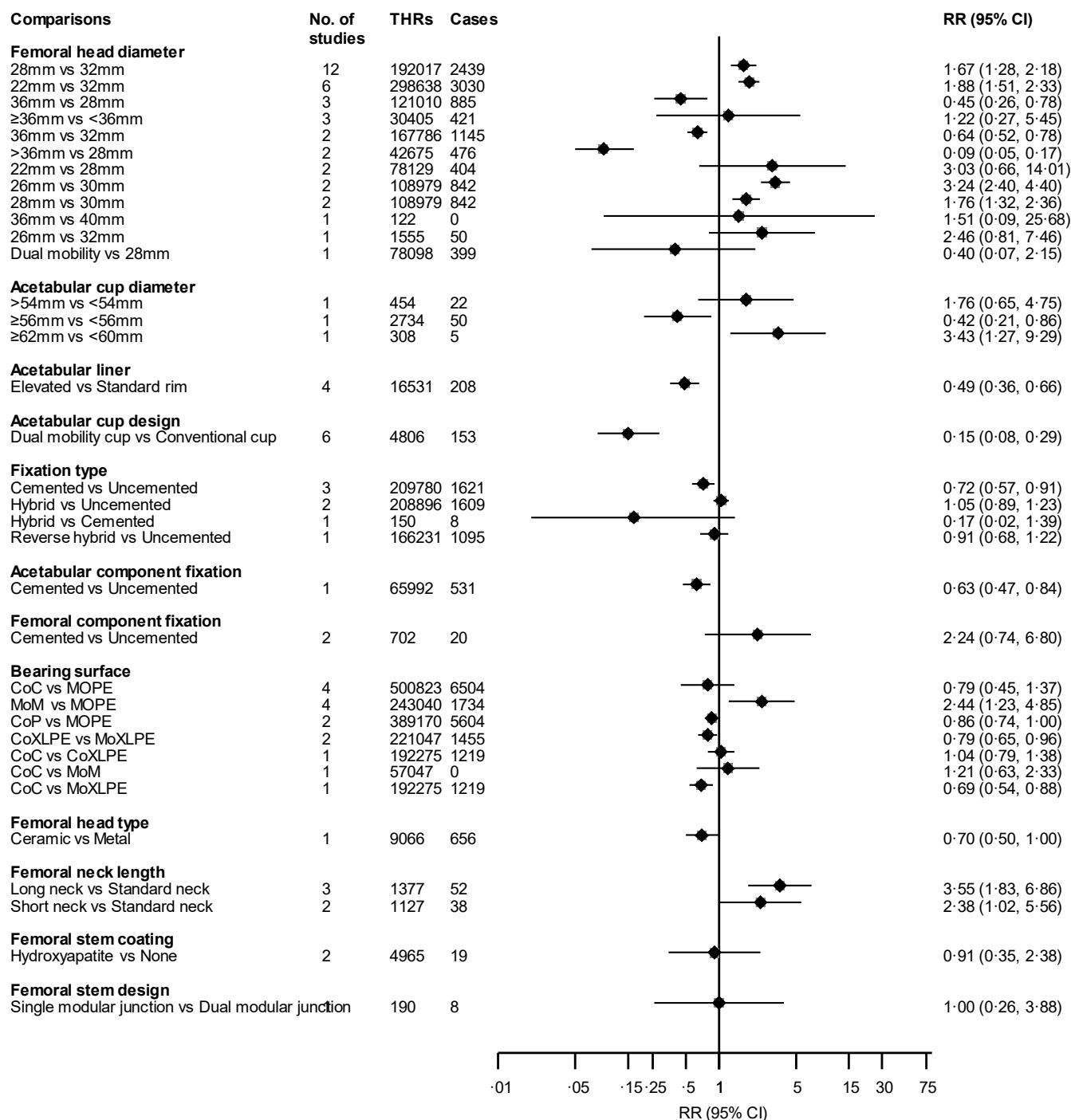
CI, confidence interval (bars); RR, relative risk; THR, total hip replacement

Appendix 24. Risk of dislocation comparing a posterior short external rotator and capsule repair versus none, grouped according to study level characteristics



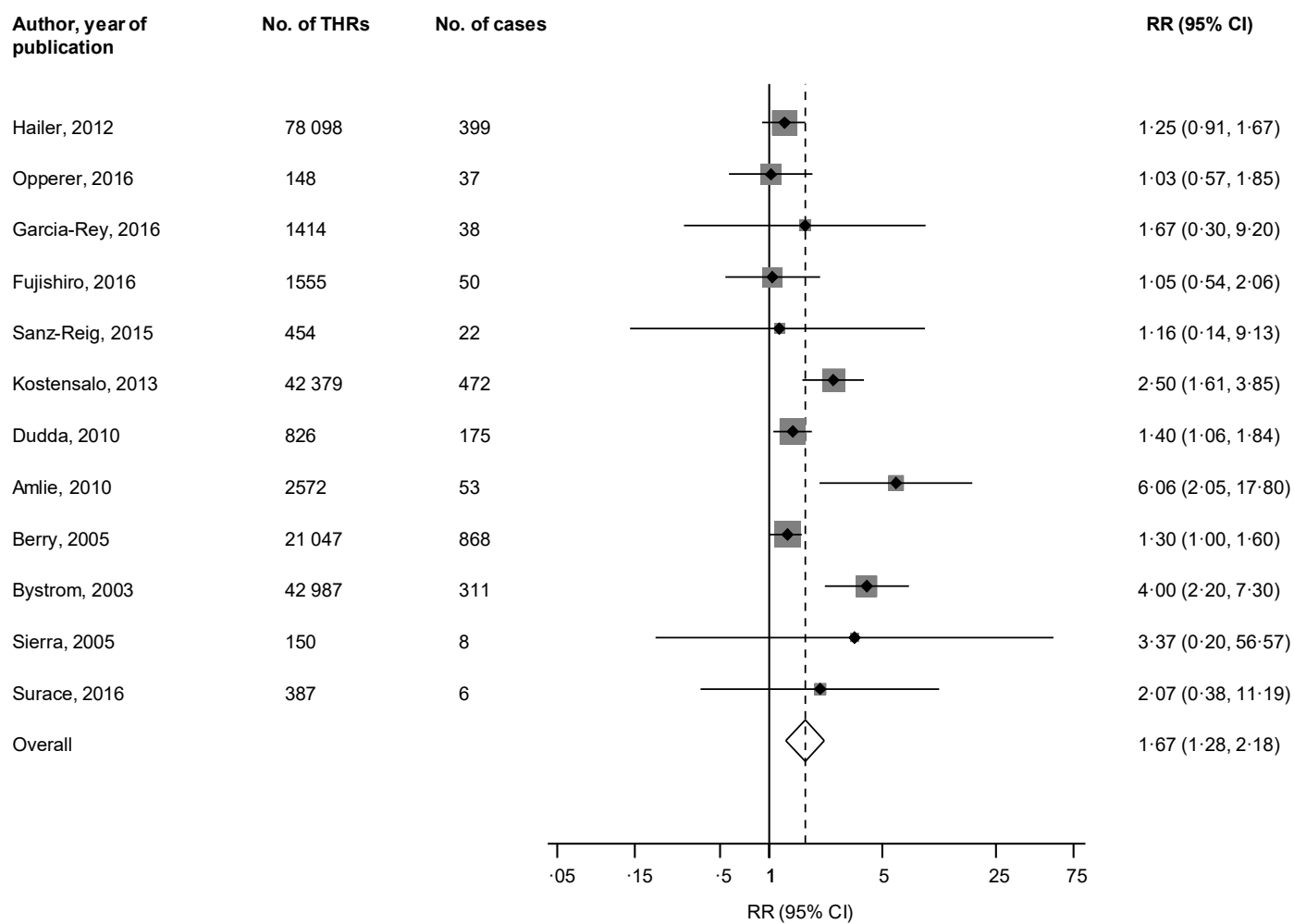
CI, confidence interval (bars); RR, relative risk; *p*-values are for meta-regression

Appendix 25. Summary associations of implant-related factors and risk of dislocation



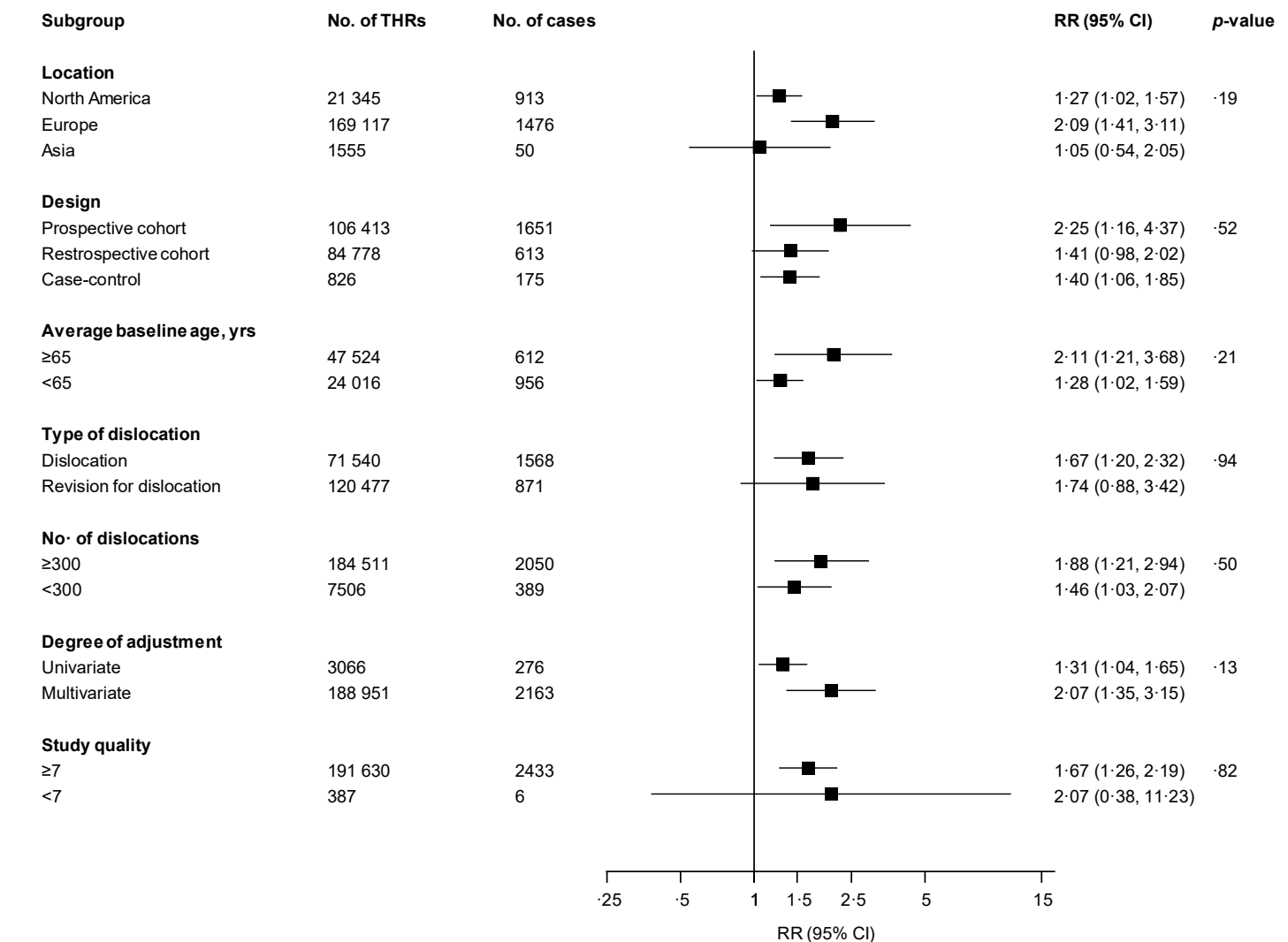
CI, confidence interval (bars); CoC, ceramic-on-ceramic; CoXLPE, ceramic-on-cross-linked polyethylene; MoM, metal-on-metal; MoPE, metal-on-polyethylene; metal-on-cross-linked polyethylene, MoXLPE; RR, relative risk; *, are number of participants or hip replacements

Appendix 26. Risk of dislocation comparing femoral head diameter 28mm versus 32mm



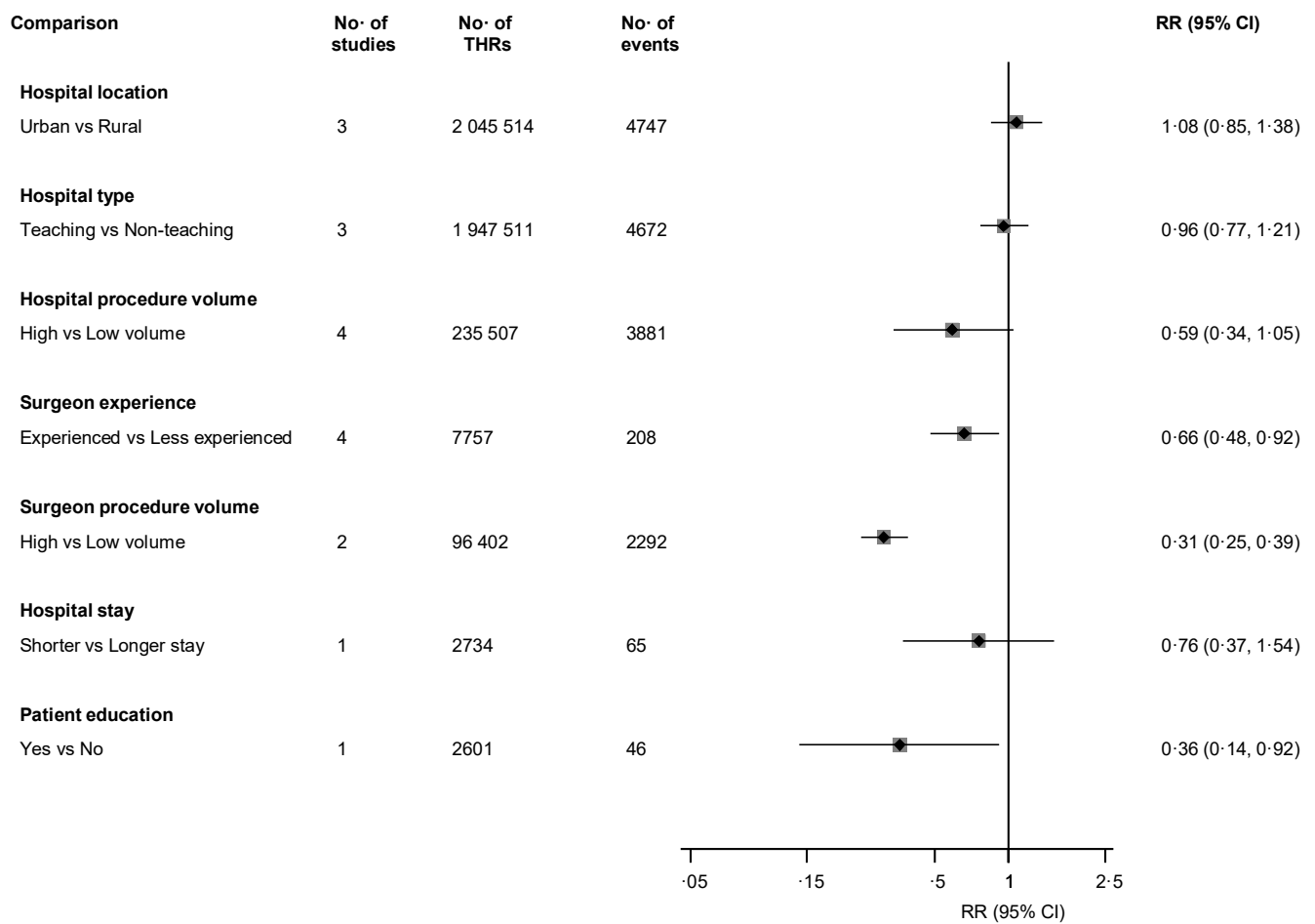
CI, confidence interval (bars); RR, relative risk; THR, total hip replacement

Appendix 27. Risk of dislocation comparing femoral head diameter 28mm versus 32mm, grouped according to study level characteristics



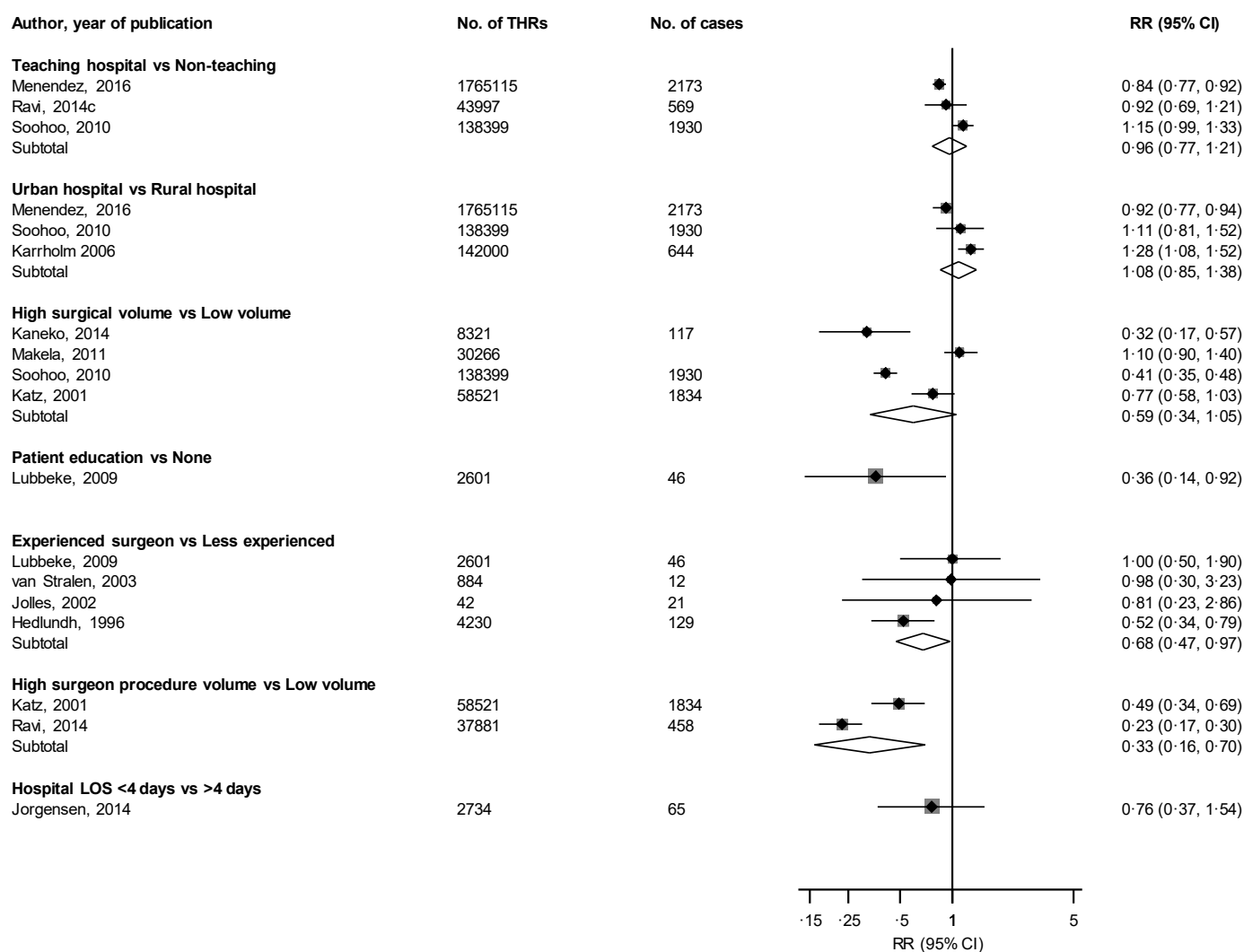
CI, confidence interval (bars); RR, relative risk; *p*-values are for meta-regression

Appendix 28. Summary associations of hospital-related factors and risk of dislocation



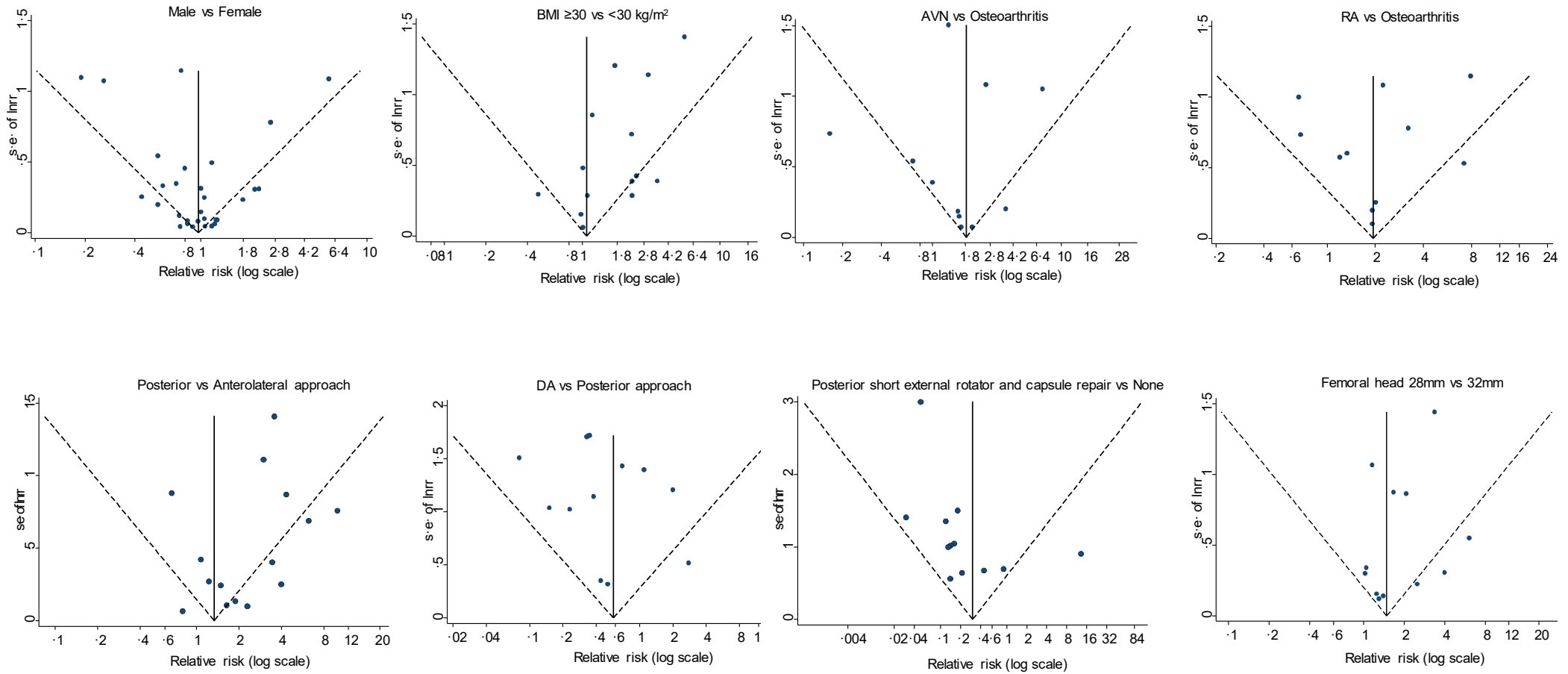
CI, confidence interval (bars); RR, relative risk; THR, total hip replacement

Appendix 29. Hospital-related factors and risk of dislocation



CI, confidence interval (bars); Hb, haemoglobin; LOS, length of stay; RR, relative risk; THR, total hip replacement

Appendix 30. Assessment of small study effects by funnel plots and Egger's regression symmetry tests



The dotted lines show 95% confidence intervals around the overall summary estimate calculated using a fixed effect model;; *P*-values for bias calculated using Egger's test were 0.88; 0.06; 0.50; 0.87; 0.08; 0.63; 0.57; and 0.22 for male versus female; BMI ≥ 30 versus < 30 ; avascular necrosis versus osteoarthritis; rheumatoid arthritis versus osteoarthritis; posterior versus anterolateral approach; direct anterior versus posterior approach; posterior short external rotator and capsule repair versus none; and femoral head diameter 28mm versus 32mm; AVN, avascular necrosis; BMI, body mass index; DA, direct anterior, RA, rheumatoid arthritis